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AN

ESSAY

On the Inveſtigation of

The Firſt Principles of Nature:

TOGETHER WITH

The Application thereof to ſolve the Phænomena

OF THE

PHYSICAL SYSTEM.

PART II.

IN WHICH

The Nature and Fuel of the Sun are phyſically inveſtigated; the real Principles of Cold and Darkneſs aſſigned; the Nature and Motion of Comets explained; the material Cauſes of the planetary Motions exhibited; the Tenet of Attraction diſcuſſed and rectified; and the Phænomena of Electricity, Gravity, and Coheſion, ſolved by the mechanical Agency of two material Principles which actuate the Univerſe, and produce all the Operations of Nature.

By FELIX O'GALLAGHER.

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ERRATA.

Page 320 Laſt line for *quality* read *quantity*,
321 24 for *influent* read *efluent*,
340 20 for *familarity* read *ſimilarity*,

For Errata to the Plates ſee laſt Page.

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LECTURE VIII.

The Nature of the Sun and its Pabulum inveſtigated.

SECTION I.

Neceſſity of Fuel for the Sun: Qualities thereof: Comets not adequate, nor deſtined for that Purpoſe.

WE have proved, in the fourth lecture of this work, *part the firſt*, that the ſun muſt be a luminous body of a fiery nature, endued with its own native heat and light. In the ſeventh lecture of the ſame firſt part, we have alſo proved that light is a continuous flowing body, whoſe parts are in ſucceſſive generation and conſumption; that its motion is *in orbem*, and its motive force the expanſive vigour of the luminous body, by which it is emitted and protruded, not by diſtinct impulſes, but by a conſtant and ſucceſſive preſſion of new born matter iſſuing from its ſolar fountain. This being ſo, it neceſſarily follows, that he muſt have a perpetual ſupply of alimental matter flowing into him for the preſervation of his magnitude and the repleniſhment of thoſe immenſe and unremitting effuſions, which he is ever pouring forth into the ſurrounding ſpace, to warm and illuminate the planets; for we know from experience, that the light of a candle, lamp, or fire depends on, and emanates from the flame of each; and we know alſo that this flame is nouriſhed and ſuſtained by a pabulum or fuel, which is conſumed or waſted, according to the quantity of light that iſſues from the flame; and that, when this food or fuel is exhauſted, the flame expires and yields no more light. Experience, therefore, ſhews, that a conſtant effuſion of light depends on a conſtant flow of alimental matter to ſupply the waſte of the effuſing flame. And without conſulting experiment, from the dictates of reaſon, grounded indeed on a knowledge of nature, we might at once pronounce, that it is inconſiſtent with the nature of body, to retain its magnitude, quantity of matter and vigour, while it effuſes its ſubſtance, without deriving from ſome convenient ſource a ſupply equal to the loſs it ſuffers by ſuch effuſions. From reaſon, therefore, analogy and univerſal experience we muſt conclude, that the ſun has a conſtant ſupply of aliment, to prevent the reduction of his magnitude and vigour, and to repleniſh the prodigious and unceaſing effuſions of his ſubſtance in the form of light. For to ſay that ſome innate virtue, or immaterial quality reſtores his magnitude and quantity of matter, notwithſtanding his perpetual emiſſion of light, which we have proved to be a material ſubſtance, would be an unphyſical and unintelligible notion, contrary to the ſecond and third propoſitions of the firſt Lecture; and to ſay, that this is performed by the conſtant care and direction of Providence, is either giving no explanation, or feigning a new and perpetual creation of matter contrary to experience, and inconſiſtent with that perfection, which the divine Wiſdom and Power originally gave to the great machine of the univerſe.

In order, therefore, to inveſtigate the nature of the ſun's alimentary matter (which has hitherto continued in the obſcurity of nature's *arcana*) on account of the immenſe diſtance of the ſun, we muſt proceed by analogy, and examine thoſe fuels and *pabula* of fire and flame, which are within our reach. Of theſe the moſt ſtriking and conſpicuous is gunpowder, of which ſuch is the inflammability, that any quantity of it, when dry and ſituated in open air, being touched with a ſpark of fire, will in an inſtant be inflamed and conſumed. The firſt obſervation that preſents itſelf on this phænomenon is, that the heap is not burned through in a diametrical direction from one ſide to the other; for in this caſe, grains would be ſcattered on both ſides, and the flame would not aſſume a ſpherical form; neither would the exploſive force act, as from effects it is known to do, by a central repulſion of equal vigour on every ſide, but would urge in forward direction, as does the fire in a train. This may alſo be inferred from another conſideration; flame is enlivened by air, and dies *in vacuo*; and powder may be conſidered as the digeſted food for flame; conſequently when it kindles, the flame ſhould ſubſiſt between the air and powder, in order to be fed by both: and this is perceivable in other inſtances; for if a bowl of heated ſpirits be ſet on fire, the flame continues on the ſurface of the liquor, where it at once enjoys the air and the ſpirit, and feeds on both. In powder it proceeds in the ſame manner, but its mode is not diſcernible; for, with a rapidity equal to that of electricity, the flame is propagated round the ſurface of the heap, and preſſed in on all ſides by the ſurrounding air with a moſt violent *conatus* towards the centre, where theſe concentrating efforts of the elaſtic flame produce a centrifugal repulſion exhibited by the ſpherical exploſion.

Hence we may judge of the operations of a permanent flame, which may hereafter illuſtrate the nature of the Sun. This flame, that of a candle, for inſtance, is ſurrounded on all ſides by a vault it moulds for itſelf in the ambient air, whoſe preſſure confines, and whoſe ſpirit enlivens the emboſomed flame. In this aerial furnace the flame aſſimilates the tallow or fuel to its own form, and then ſublimates it to the eſſential purity and extreme attenuity of light. But ſhould not theſe exertions to transform its fuel diminiſh its torrifying power, and abate its expanſive force? they certainly do; otherwiſe why ſhould gunpowder be ſo rapidly changed into flame, while the conſumption of a candle is ſo ſlow and gradual? the difference ariſes from the nature of the fuel; for the preſſure and enlivening ſpirit of the air are common to both: the candle, though fuel, is not eaſily transformed as the powder, which being as we have ſaid, ready digeſted for flame, is no reſtraint upon the expanſive vigour or conſuming power of fire: but fuel of difficult digeſtion will not yield much light or heat; becauſe the expanſive vigour, which ſhould ſend forth both, is employed and ſpent in transformation. Moiſture, we know, is a clog to expanſion; and a great humidity will entirely prevent burning, for which reaſon, gunpowder, which, when dry, inflames inſtantaneouſly, will, when damp, only emit a feeble glow without heat or vigour. The ſame thing is obſervable in every other kind of fuel, as turf, wood, coal, &c. which ſhews, that in proportion as fuel is hard to be conſumed, it becomes unqualified for yielding heat and light. This is alſo true in the converſe; for of different kinds of fuel, ſuppoſe all equally dry, that, which burns moſt readily and lively, will diffuſe moſt heat and light. Wood, for inſtance, or turf, being eaſily conſumed, will, if well ſupplied, make a moſt bright and lively fire; and chips, becauſe more eaſily transformed than a block of the ſame wood, will emit more flame.

From ſuch effects, along with other obvious conſiderations taken from common and univerſal experience, we may judge, what fuel will be of the eaſieſt digeſtion. Along with the fuel nature, which conſiſts in an unctuous or bituminous ſubſtance, the matter ſhould be dry, of a black colour, and neither deſtitute of heat, nor of an intenſe or heavy conſiſtency. It ſhould be dry, for moiſture extinguiſhes fire and prevents kindling; no fuel can be enflamed until the moiſture is evaporated. It ſhould be black, to abſorb the fire or light that is applied to kindle it; for we find that wood, paper, cloth, linen, weeds, plants, or any other combuſtible matter, whether white, green, red, &c. muſt all turn black, either by flame or friction, before they kindle; as if every concrete ſubſtance of theſe bodies were a repellent to light or fire, except that of a black colour, which by its nature abſorbs both. We find that black cloths of every kind are warmer than thoſe of any other colour; now the ſubſtance and texture of theſe being the ſame in every thing elſe, the difference muſt be in the matter of the dye that makes them black, which abſorbs the matter of heat abundantly; and even to accelerate the burning of ſubſtances, that are not black, before they are expoſed to the mirror or burning glaſs, their ſurface is covered with lamblack, ſoot, ink-powder, or ſome other black matter. It is needleſs to add, that coal, turf, &c. deſtined by nature for fuel, are of a black colour, as are alſo tinder and gunpowder, the moſt inflammable of all bodies. A ſlight heat is another uſeful quality in fuel. Rectified ſpirits, we ſee, when ſomewhat heated, kindle with a flame as readily, as gunpowder kindles with a ſpark; becauſe a moderate heat, as well here as in other ſubſtances, awakens the elaſtic fiery matter they contain, which, having expanded and opened the parts, catches and introduces the external flame, as the vapour of an extinguiſhed candle will lead a diſtant flame to the ſmoaking wick. Exceſſive denſity is inimical to fire; fuel, in general, is of no great ſpecific gravity; wood and turf are lighter than coal; and good coal of all hard foſſils is the ligheſt.

Theſe qualities, therefore, ſhould be the characteriſtics of Comets, were they deſigned by the Creator as fuel for the ſun, to preſerve his light, heat, vigour, and magnitude. They ought, like our coal, to be black, for the abſorption and retention of the ſolar light and heat, which would warm and agitate their combuſtible matters, and thus baniſh that humid atmoſphere they are ſuppoſed to collect and bring with them from the frigid regions of Aphelion, which would otherwiſe damp the ſolar flame. Their acceſs alſo, for this purpoſe, ſhould be ſlow and gradual, and not ſo rapid as their motion is obſerved in Perihelion. Nevertheleſs, their colour is not black, but of a duſky bright or golden hue, like amber, which is a bituminous combuſtible matter, lighter and leſs denſe than coal, and therefore, I apprehend, more quickly conſumed. If comets then were the only fuel deſtined to ſupport the ſun, being at the ſame time, as we muſt conclude from appearance and analogy, (for fanciful hypotheſes are not to be admitted) bodies of amber, (a quick tranſient fuel) they ſhould be more numerous than the ſtars. The ſun would require more than one for his daily waſte, according to what we experience in a candle or fire; for the latter will burn each day more than its bulk of coals, and the former will conſume a quantity of tallow far exceeding the ſize of its blaze.

Now a thouſand Comets would ſcarcely make a body as large as the ſun; if, therefore, they be of an hard bituminous nature, like amber or good pit coal, a thouſand, at leaſt, would be neceſſary for the ſun's daily ſupport; and we ſhould every night ſee the heavens crowded with blazing ſtars moving towards Perihelion; ſo that comets inſtead of being the rare phenomena of ſixty, eighty, or an hundred years, would be as familiar and conſtant appearances as the fixed ſtars themſelves.

But to obviate an objection, let us ſuppoſe, with the common opinion, comets to be the moſt denſe and durable matter in nature; ſo that the few we ſee are ſufficient for the ſun's preſervation. In this caſe they would be a fuel very improper for the ſun, as his expanſive vigour ſpent, according to foregoing remarks, in diſſolving the ſtubborn maſs, could diffuſe neither light nor heat in any abundance; particularly on the arrival of a new comet, vegetables and animals muſt periſh for want of heat; for we find vaſt difference between the heat a fire affords when coals are juſt thrown on, and after the coals have kindled; it is at firſt dark and feeble, afterwards bright and ſtrong; and its latter ſtate of vigour ſcarcely laſts twenty times longer than the weak naſcent ſtate of its growing heat and flame. A comet, therefore, of ſuch denſity as to ſerve the ſun for twenty, ſixty, or an hundred years, ſhould certainly render him duſky and defective for two, three, or ten years, before he could reſume his uſual ſtrength and ſplendour. This ſhould be the caſe, particularly as they come with ſuch rapidity from Aphelion, charged with cold and moiſture. Nor ſhould the want of heat and light, thus induced by a new comet, be partial or temporary, like that ariſing from intervening clouds or freezing winds; for the whole earth ſhould be deprived of the ſun's enlivening heat and benign influence, not for a month or ſeaſon, but for years together. Famines then would be more tedious and ſevere than that of Egypt, and the deſtruction of vegetables and animals more univerſal and fatal than the plagues with which that country was afflicted. Famine, peſtilence and deſolation would return periodically every ſixty or an hundred years with each new comet to be conſumed. The ſun alſo, thus periodically renewed, ſhould be as changeable in vigour and luſtre as the phaſis of the moon: hiſtory would be ſwelled with direful prognoſtication; and mankind would ſhudder at the approaching obſcuration and wane of the ſun. But no, thank heaven! the Creator has made every thing permanent and adequate for our comfort and preſervation. And if He has appointed a periodic variety and ſucceſſion of ſeaſons, it was to render life leſs irkſome. The ſun and the air, on which life and vegetation depend, are permanent and unvaried, except that the latter changes its temperature with the ſeaſons: we experience not thoſe ſad viciſſitudes, thoſe general calamities, and direful privations of light and heat; on the contrary, we find that, if one part of the earth, from intervening clouds, nipping winds, or continued rains labours under an accidental and temporary diſtreſs, other parts are ſo bountifully indulged with heat, light and vegetation, as to ſubſiſt with eaſe and alleviate the diſtreſſes of leſs favoured climates. A general defection or failure in the principles of nature, even to the heathen philoſophers, ſeemed inconſiſtent with the exiſtence and perfections of the Deity. Hence, as we have before remarked, Dioniſius, on the day of the crucifixion, ſeeing an obſcuration of the ſun, which could not be an eclipſe, pronounced the world at an end, or the Deity under violence; whereas, in the ſuppoſition we attack, that darkneſs, far from being uncommon, ſhould attend the ingreſs of every comet to the ſun; but the fact is, that was the firſt obſcuration of the ſun that had ever happened, except in the caſe of an eclipſe, which is an interception, not a privation of light; we muſt, therefore, upon the whole conclude, that Comets are not the fuel deſtined by Providence to ſupply the ſun's waſte, and preſerve his quantity of matter, magnitude and vigour.

SECTION II.

The Nature and Compoſition of the Sun inveſtigated: the Conjectures of Sir Iſaac Newton on that Subject corrected.

HAVING proved the inconſiſtency of the only conjecture, which has hitherto prevailed with regard to the fuel of the ſun, we ſhall now continue our inveſtigations, in hopes of diſcovering a more natural and adequate ſource of his vigour and permanence; but firſt it is neceſſary to form a juſt conception of his nature and compoſition. The expanſive power of the elaſtic matter has been repeatedly exhibited; but its effects are no where more conſpicuous than in Papin's Digeſter. In this confined ſtate, though damped with humidity, when expanded by heat it ſwells to the full dimenſions of the veſſel: here it is driven back from all parts to the centre by the unyielding metal, and forced to work violently on the ſubjects encloſed. Theſe contained bodies, therefore, it penetrates on all ſides, pervading their moſt intimate particles, and ſo irritates their concrete fires, that they break forth, diſſolving the moſt minute and intimate ſtamina of the bodies, in which they were contextured. The fires, thus enlarged from the moſt intimate and minute parts of the body, but at the ſame time confined within the veſſel, form a moſt elaſtic and penetrating fluid, whoſe violent reverberations diſſolve the other ſubſtances, and reduce all to an uniform jelly.

Such alſo are the efforts and contorſions of gunpowder flame in the chamber of a mine or piece of ordnance, except that they are more forcible and rapid, the elaſtic matter in theſe inſtances being more ſublimated and unreſtrained by humidity; for the ball or incumbent weight cannot be thrown off, until the ſublimation is performed, and the expanſion is in force. Indeed theſe operations are inſtantaneous; however we muſt reſolve them into ſtages, in order to form juſt ideas, and render them ſuſceptible of explanation. The flame of a candle alſo operates in a ſimilar manner: this, we have ſeen, is a kind of aerial furnace, where the tallow is elaborated into flame, and again further ſublimated into light through the preſſure and enlivening reverberations of the air, with which it is ſurrounded. All theſe operations are produced by the ſame eſſential cauſe, to wit, the expanſive power of the elaſtic matter, which being ſet in action by heat, and counteracted by ſome confining force, reverberates more or leſs forcibly, and, by its powerful action, produces the various effects here recited according to the circumſtances in which it operates. In the digeſter a ſtrong metal pot was the confining cauſe, which, being powerful, the reverberations were proportionably forcible; but the moiſture abated their force and determined the nature of their effect. The reverberations of the gunpowder flame were alſo adequate to the reſtraining force, particularly as they were not clogged by moiſture; and ſuch is the connection between the ſtrength of the reverberations and the compreſſing force, that a gun ill rammed will make but a feeble diſcharge; whereas, if well rammed, it will explode with great force and a loud report. The flame of a candle is leſs compreſſed than either of the former fluids, and its reverberations are therefore leſs violent. However, it is compreſſed on all ſides by the weight of the atmoſphere, which counteracts its expanſive force, ſo as to cauſe reverberations capable of elaborating and transforming the tallow into flame, and farther ſublimating it into light. From all which it may be inferred, that the improvement of expanſion to any degree of force, depends on the compreſſive force by which it is counteracted.

CONSECTARY. I.

If then an immenſe expanſion be neceſſary for, or really diſcovered in the ſun, he ſhould be acted upon on all ſides by an immenſe compreſſive force, as well to give vigour to this expanſion, as to prevent his exploding, like gunpowder in the open air.

The ſame inference may be drawn from the conſumption of his fuel; for to digeſt much or difficult fuel, ſtrong reverberations are neceſſary; but ſtrong reverberations require a ſtrong compreſſive force.

The flame of a candle, though acted upon by a preſſure, which ſhould ſeem uniform, is not however ſpherical; becauſe, naturally aſcending, it rarifies moſt the air vertical to it, and by thus diminiſhing the preſſure in that direction, moulds for itſelf an oblong vault; but the flame of a candle juſt after being lighted, as well as the ſparks which are ſtruck from flint and ſteel, or which fly from fiery glowing metals, are ſpherical, not having had time to rarify the air immediately over them. And doubtleſs, every kind of fluid which has not a propenſity to aſcend, or to flow more on one ſide than another, being equally preſſed on all ſides by the air, muſt be globular, as are the bubbles which boys form by blowing ſoaped water from a tobacco pipe, and likewiſe theſe made by glaſs-blowers: whence the ſecond confectary.

CONSECTARY II.

Since the ſun is ſpherical, the preſſive medium, deduced in the foregoing conſectary, with which he is ſurrounded, muſt be uniform.

Every body within our knowledge and experience, which is naturally luminous, that is, which effuſes light and heat, is a liquid flame; for ſuch is the luminous part of a candle, lamp, fire, or any other cumbuſtible matter that yields light: burn theſe combuſtible ſubſtances to aſhes, and, unleſs they flame, they will afford no ſignificant light. Iron, coal, foſſils and vegitables, if they burn without flame, altho' they be red with heat, afford a light ſo dim, as ſcarcely to illuminate a body or ſpace quite contiguous. Some bodies will conſume to aſhes without being red, and in this caſe they will burn a body in contact with them without illuminating it: whence a third conſectary appears evident.

CONSECTARY III.

Nothing but liquid flame can emit light and heat to a diſtant body or ſpace.

Even inflammable matters, ſuch as oil, tallow, pounded rozin, ſulphur, or gunpowder, when laid on hot iron, may burn, and yield a dim glow, but will not give a ſignificant light, until they kindle into flame. This liquidity of flame might have alſo been deduced from our obſervations on the flame of a candle; for the expanſive exertions and reverberations, by which alone the wax or tallow is digeſted in the wick, and elaborated to the form of flame, are operations only imputable to, or conſiſtent with, a fluid ſubſtance.

It is ſo alſo with light extracted from bodies by friction. Two pieces of wood, as before remarked, when dry and briſkly rubbed in the open air, warm, grow black, and ſome time after kindle; they may grow hot, indeed, on account of the bridled ſtrugling motion of the elaſtic matter crouding to the fricted parts; but do not flame, until the elaſtic matter ſtill more excited iſſues forth in copious fume. This fume of the elaſtic matter, vellicated and enlivened by the conflict of the air, begets flame, which will alſo happen if this, or any other fuel be confined in a metal veſſel on the fire; for it will there burn, but will not blaze until the air is admitted, when the claſh, or concourſe of the flame and air immediately begets flame and light.

Thus in both caſes flame is generated, which at once feeds on the fume, which gave it birth, and refines it into its own form, in which only it can give light. It is after the ſame manner that the tip of the denſe hot vapour which iſſues from wood or coal on a briſk fire begets flame, which then ſhoots along the ſteaming vapour, until it lays hold on the fuel, whereon it will ſettle, while ſuſtained by the fumes that iſſue from it; but as ſoon as thoſe effuſions ceaſe, the flame will die away and leave no remains of the fuel but inert aſhes: whence two other conſectaries.

CONSECTARY IV.

It is not the inert, but the elaſtic matter of a body that turns to light, and forms that iſſuing fume, which, according to Newton, turns to flame.

CONSECTARY V.

Flame alone can be the ſource of native light, whoſe degree of fluidity muſt be prodigious, ſince it exalts and refines its parent fluids, to wit, vapour and air: whence again it follows:

CONSECTARY VI.

That a luminous body muſt not only be fluid, but the moſt refined and exalted of all the fluids we have any knowledge of in nature.

By a luminous body, we underſtand a body endowed with ſtrong native light and heat, and conſequently with expanſive vigour to propel them to a conſiderable diſtance. Such a body then, from what has been ſaid, muſt be a liquid flame; and the greater the diſtance, to which this light and heat are propelled, ſo much greater muſt be the expanſive vigour of this body; for cauſes are as their effects, and effects as their cauſes; from which principle it alſo follows:

CONSECTARY VII.

That, the greater the expanſive vigour of a luminous body, the greater muſt alſo be its effuſions and waſte, and the more copious likewiſe muſt be its ſtore of pabulum to ſupply the waſte. This has been illuſtrated in the former ſection.

CONSECTARY VIII.

And converſely, where the emanations are prodigious, the expanſive vigour muſt be proportionably great. This is clear from our experience of a lamp or candle.

If on the contrary a luminous body be not thus conſtantly ſupplied, but refreſhed at intervals, as our fires are with a box of coals, it ſhould decay and fail both in vigour and dimenſions, and undergo all the changes obſervable in a common fire during the courſe of a day. And, as we have ſeen but from another conſideration, ſuch ſhould be the caſe with the ſun, were his only ſupport an odd comet from time to time.

In rejecting this opinion, and pronouncing comets not to be the food of the ſun, we are ſupported by Newton's fourth rule for philoſophizing. This rule is deſigned for excluding arguments and concluſions founded on hypotheſis and ſpecious conjectures, and for admitting none, but thoſe grounded on experiment. Now, our concluſion againſt that opinion is eſtabliſhed on facts and experience within the reach, and under the eye of every obſerver. It is drawn from the ſimilarity, or rather ſameneſs of effects and operations, whence according to our axioms, the principles and cauſes ſhould be the ſame.

This mode of proceeding is the only infallible guide to inveſtigate the cauſes, nature and principles of things beyond our reach; for it is in the glaring effects and ſtriking operations, which fall under conſtant experience, that we are to diſcover the firſt cauſes and principles of action which nature employs. This diſcovery being made, the ſimplicity of nature, founded on the power and wiſdom of the Creator, convinces us, that the cauſes and principles of diſtant, but ſimilar operations, muſt be the ſame; we ſhall therefore, from our preceding concluſions, educe the nature of the Sun.

The ſun is a ſpherical luminous body, compoſed of liquid flame, and endowed with a prodigious expanſive power, which acts equally on all ſides from centre to ſurface; by this power he diſſeminates his effuſions of heat and light throughout the planetary ſyſtem, and would by its centrifugal propenſity be immediately diſſipated, were he not compreſſed on all ſides by the powerful and uniform action of an incumbent medium.

Since the light of the ſun is ſo ſenſible at this great diſtance, the immenſe body of fluid which ſurrounds him, and preſerves his form, muſt be tranſparent: *Quere*, may not this fluid have ſome affinity to our atmoſphere, and animate his vigour, as air does that of a candle-flame? May it not even be the pabulum for the ſun's ſupport?

Sir Iſaac Newton agrees with us in the neceſſity of an atmoſphere about the ſun, not ſo much to prevent the exploſion of his ſubſtance, or to preſerve his globularity (which were the reaſons we aſſigned) as to prevent extraneous bodies from exploding from his ſurface in fume and vapour. Theſe extraneous bodies, for whoſe ſake he introduces an atmoſphere to prevent their riſing up and going off in the form of vapour, we ſuppoſe, are the comets, which, according to him, nouriſh the ſun. Therefore, as he differs widely from us in his conception of the nature and pabulum of the ſun, we ſhall now take into conſideration his opinions, and compare them with our eductions on the ſame ſubject.

‘ And are not’ (ſays this great philoſopher in the 11th query at the end of his opticks) ‘ the ‘ ſun and fixed ſtars great earths vehemently ‘ hot, whoſe heat is conſerved by the greatneſs ‘ of the bodies, and the mutual action and re- ‘ action between them and the light they emit; ‘ and whoſe parts are kept from burning away, ‘ not only by their fixity, but alſo by the weight ‘ and great denſity of the atmoſpheres incum- ‘ bent upon them, and condenſing the vapours ‘ and exhalations which ariſe from them. For ‘ if water be made warm in any pellucid veſſel ‘ emptied of air, that water in the vacuum will ‘ bubble and boil vehemently, &c.’ Having ſhewn the neceſſity of an heavy atmoſphere, he thus concludes by illation: ‘ In like manner ‘ the weight of the atmoſphere that lies upon ‘ the globe of the ſun may hinder bodies there ‘ from riſing up, and going away from the ſun ‘ in the form of vapours and fumes, &c.’

He treats of comets in the 42d prop: of the third book of his *Principia*, towards the concluſion of which he ſpeaks thus: ‘The ‘comet which appeared in the year 1680, was ‘in its perihelion leſs diſtant from the ſun than ‘by a ſixth part of the ſun's diameter, and be‘cauſe of its extreme velocity in that proximity ‘to the ſun, and ſome denſity of the ſun's ‘atmoſphere, it muſt have ſuffered ſome re‘ſiſtance and retardation; and therefore being ‘attracted ſomething nearer to the ſun in every ‘revolution, will at laſt fall down on the body ‘of the ſun. Nay, in its aphelion, where it ‘moves ſloweſt, it may ſometimes happen to ‘be yet farther retarded by the attraction of ‘other comets, and in conſequence of this re‘tardation, deſcend to the ſun. So fixed ſtars ‘that have been gradually waſted by the light ‘and vapours emitted from them for a long ‘time, may be recovered by comets that fall ‘upon them. From this freſh ſupply of new ‘fuel, thoſe old ſtars acquire new ſplendour ‘and may paſs for new ſtars. Of this kind ‘are ſuch fixed ſtars as appear on a ſudden ‘and ſhine with a wonderful brightneſs at ‘firſt, and afterwards vaniſh by little and ‘little, &c.’

This celebrated philoſopher in his notions of the fixed ſtars, which are allowed to be ſo many ſuns, admits that they acquire new ſplendour, when their waſte is ſupplied by comets; and afterwards gradually decay until they are again recruited by a new ſupply of fuel, which coincides exactly with our aſſertion of periodic changes in the ſun's magnitude and luſtre, were his waſte of ſubſtance to be ſupplied with a pabulum of ſuch hard, unfrequent, and durable bodies as comets. We have already ſhewn that he agrees with us alſo in the neceſſity of a preſſive atmoſphere, to prevent both exploſion and too laviſh a waſte of the ſolar ſubſtance. But in his conjectural reaſoning on the ſun and ſtars, he ſeems to have forgot the rule of philoſophizing lately cited to prevent hypothetic concluſions; he even ſeems to invert the order of reaſoning, by illuſtrating things more adjacent and conſpicuous by things more remote and obſcure. He ſhould certainly have obſerved, that the decays and renewals, which he explained in the ſtars, and repreſented as ſo ſenſible in them, ſhould be far more conſpicuous in the ſun, on account of his greater vicinity, were he ſuſtained by comets.

As he alſo differs from us, in aſſigning the nature and ſubſtance of the ſun, which we have by analogy educed from general and well-known experience to be a body of liquid flame, and which he, without argument or eduction, conjectures to be *a great earth vehemently hot*, we ſhall diſcuſs his notion.

If then the ſun was an earth, he muſt long ſince have become a body of liquid glaſs, as would our earth by ſo vehement an heat, as we know ſubſiſts in him; in which caſe, he would be incapable of emitting ſo much heat and light, as we find he does, or as he ought to do, being, according to our eductions, a body of flame.

To prove this aſſertion, we ſhall adduce the power of a mirror or burning glaſs. The effects of theſe inſtruments are pretty generally known. The celebrated mirror made by the father and his two ſons, the Villets of Lyons, as deſcribed by doctor Boerhaave, (v. I. p. 134, 135) was prodigiouſly powerful. This ſpeculum was made of a metalline ſubſtance, of about 400lb. weight, in the form of a concave ſpherical ſegment, 43 inches in diameter, convening the light in a focus of half an inch diameter, and at the diſtance of three feet and a half from the vertex; whence the plain area of the ſpeculum is to that of the focus as 7396 is to 1, in which proportion it condenſed the ſolar beam that it reflected. Now the diſtance from the earth to the ſun is to the ſemidiameter of the ſun, as 240 to 1: the intenſity of light, therefore, at the ſun, is to its ſtrongeſt beam here, as 57600 to 1; and this in the ſuppoſition, that his heat ſuffers no abatement from the extreme cold of the clouds, atmoſphere, and ætherial ſpaces in its paſſage to us. But how improper this ſuppoſition is, will readily appear from the exceſſive coldneſs of the winds, which blow over high mountains or ſnowy tracts; however, making no allowance for the ſun beam's loſs of heat from the coldneſs of the upper regions, the intenſity of heat, at the ſun's ſurface, ſhould be at leaſt ſeven times greater than in the focus of Villets' mirror: but the heat of this focus, had the ſun beam paſſed through temperate regions, and met with no contingent diminution of heat, would, undoubtedly, be ten times greater than it is after ſuffering that abatement. And, comparing the heat of a candle, or fire, when we touch the flame, to the heat of either, at the diſtance of ſome yards, even tho' collected to a focus, we find a vaſt difference. The heat of the ſun at its ſurface is, therefore, undoubtedly above 70 or 100 times greater than that of the aforeſaid focus. The ſcrutiny of calculation may, perhaps, extenuate and impoveriſh the force of nature; for, were we on this ſubject, to liſten to the firſt conceptions and moſt obvious ſuggeſtions of reaſon, a flame that diffuſes thro' the whole ſolar ſyſtem a light and heat, which the other could ſcarcely afford, we might almoſt ſay within the compaſs of an egg ſhell, but at moſt within a ſpherical ſpace of two or three feet radius, a flame, I ſay, like the former, would appear many million of times more intenſe than the latter. However, let that be as it may, ſuch was the power of this mirror, according to the author before-mentioned, that in a moment it would fuſe any of the ſix metals, as alſo all the ſemi-metals, upon which the experiment was made; rocky and ſtony bodies were by it inſtantly melted and vitrified; even bones, whoſe aſhes reſiſt fire, and which are therefore uſed by chymiſts to make copelling teſts, were, in the twinkling of an eye, melted in its focus, as were likewiſe bricks, clay, ſand, crucibles, marble, jaſper and porphiry; and, laſtly, the very fire-ſtones, which maſons uſe for building furnaces, for fuſing iron and ſeparating it from its exceſſively hard foſſil ore: all thoſe ſubſtances immediately melted and vitrified in its focus.

Let us now conſider this matter a little further: are not theſe the hardeſt bodies found on the earth? Have any been yet diſcovered ſo hard, ſo impervious to fire, or leſs combuſtible, than ſtones, metals, marble, porphry, crucibles and fire-ſtones? yet all theſe are inſtantly melted and vitrified in this focus. What, then, ſhall we ſay of the ſun? How inſtantaneouſly would he not vitrify the whole globe of the earth at his ſurface, even were it one ſolid block of marble? Since this focus, this ſmall and faint image of the ſun; this collection, I may ſay, of a few rays reduced in vigour from the chilling regions they have paſſed thro', will inſtantly vitrify a ſcrap of marble, would not the whole earth, nay, a thouſand earths, be inſtantly vitrified in the ſun? for the ſun's diameter is to that of the earth as 1526 to 1; his magnitude, therefore, is between 3 and 4 million times greater than that of the earth; conſequently, a million earths and a million comets would be vitrified in the ſun as ſoon as a ſcrap of marble in this focus. And even the ſun himſelf, had he ever been what Newton ſuppoſes him to be, to wit, a great earth endowed with the heat experience ſhews him to poſſeſs, ſhould immediately have become a complete maſs of vitrious matter.

This is the inevitable conſequence of ſuch a ſuppoſition: we ſhall now purſue this neceſſary conſequence, and ſhew how inconſiſtent even this ſecond ſtate would be with the functions and effects of the ſun. We have already inſinuated, that were the ſun a vitrious body, he could not emit ſuch effuſions of light and heat as we experience from him; and with the ſtrongeſt reaſon; for we have ſhewn the cauſe of light to be flame. Newton calls this flame a vapour heated red hot, that is, ſo hot as to ſhine, &c. a notion probably taken, and eaſily illuſtrated from the various ſtages of a culinary fire; for ſuch a fire will flame, as we have obſerved, and give a diſtant light, while the fuel contains and exhales in fume our elaſtic matter, which between air and its own heat is elaborated into flame: but when this exhaling or fume-making matter is exhauſted from the fuel, it burns in the form of red coals, emitting heat or light, but to a very ſmall diſtance. The red coals, thus deprived of expanſive vigour, by loſing the ſubſtance, to which it inheres, dwindles into aſhes, emitting but a feeble gleam. Aſhes, therefore, muſt be void of every expanſive inflammable matter, or, as we have ſaid before, void of powers and qualities, and really inert matter; for the powers and qualities of the fuel, whereof theſe aſhes made a part, were with their active ſuſtaining ſubſtance, as we have ſeen before, carried off in the form of ſmoak, fume, and flame. Since, therefore, aſhes, (which are inert matter, void of expanſive vigour, or of any elaſtic matter,) are the only part of bodies which enters into the compoſition of glaſs, it follows, that vitrious bodies, being thus purged of every fumigating matter and all expanſive vigour, have no power to emit heat or light; but if they burn, muſt reſemble ſpent coals, which in reality is the form we ſee that vitrious matter is reduced to by a vehement heat.

This muſt inevitably be the caſe, unleſs they be conſtantly ſupplied with a fuel whoſe expanſive exhalations may break forth in fume, whence flame will again emerge capable of affording heat and light; but if this ſuppoſed fuel be itſelf void of expanſive fuming matter, the burning body will ſtill be incapable of emitting heat and light to a diſtance; becauſe neither itſelf, nor its fuel contains the matter of flame or light, or any expanſive force for effecting its propulſion. A vitrious body therefore, which we have already ſhewn to be deſtitute of this exhaling matter, cannot be fuel capable of ſupplying the deficiency of another vitrious body.

To come now to the application: we have proved, that had the ſun been once a great earth, he muſt long ſince have become a vitrious body; we have alſo ſeen, that in this transformation, he would have loſt the faculty of giving diſtant light and heat, being deprived of that fuming matter on which the effuſion of both depends: wherefore, that he might afterwards effuſe heat and light, a new ſtore of expanſive matter ſhould be ſupplied by ſome extraneous fuel. But this could not be done by other vitrious bodies, they too in their vitrifaction having loſt their fuming matter. Comets, therefore, which muſt be reduced to glaſs in their acceſs to the ſun, could not afford the neceſſary ſupply; ſo that if ſuch were the nature of the ſun and of his pabulum he could not ſend heat or light to any ſignificant diſtance. For ſuppoſing him to poſſeſs both, he would ſtill want the elaſtic fuming matter neceſſary for their emiſſion, and with regard to us, would only exhibit the faint glow of a burning coal. He would not indeed dwindle into aſhes, for his ſubſtance would be unchangeable, being already in the ultimate ſtate of burning bodies, to wit, that of vitrifaction.

Comparing then the imbecility, to which theſe ſuppoſitions reduce the ſun, with the efficacy of his heat and light in the revival of vegetation, and of the animal vigour at the commencement of ſpring, and with his more powerful effects during ſummer, when his emanations are more direct, we muſt conclude, that the ſun cannot be a great earth, that ſuppoſition being inconſiſtent with the reſt of nature. 2dly, That he cannot be a vitrious body, which would be the conſequence of the firſt ſtate. 3dly, That Comets which in the violence of his preſent heat ſhould alſo be vitrified, before they could touch his ſurface, cannot be his pabulum. Conſequently the ſun, according to our former eductions, muſt be a body of flame, which emits to us and far beyond us, abundant effuſions of light and heat to anſwer all our neceſſities, in the ſame manner as fires and candles yield a ſupply of each, proportioned to the purpoſes for which they are intended. This power ariſes from their denſe fume made red hot, as Newton expreſſes it, or as we have explained, from their elaſtic matters thus iſſuing forth, which are elaborated and ſublimated in aerial furnaces of flame, and afterwards propelled by the exertions of expanſion.

SECTION III.

The neceſſity of a ſolar Pabulum farther illuſtrated. Its ſituation and mode of Communication determined.

AS analogy is the only guide of a philoſopher in aſcertaining things beyond the reach of ſenſe, we muſt in the preſent inquiry ſet out from experience. The univerſe is a great machine, whoſe motions are produced, and whoſe operations are regulated by certain ſprings or agents, which we call firſt principles of nature. Theſe agents, no doubt, on account of the wiſdom of the Creator, are as few as the variety of operations would admit; and as operation is univerſal throughout nature, they muſt alſo be univerſal. Hence the propriety of concluding from analogy, or of explaining diſtant and extended operations of nature by the ſame laws and agents that we diſcover in the analyzation of ſimilar operations, which from their extent and ſituation, fall under the cognizance of ſenſe, and are in conſtant experience.

Now fires and candles transform and effuſe the ſubſtance of their *pabula*, and therefore require a conſtant ſupply of new matter to ſupport their vigour, preſerve their magnitude, and repleniſh their waſte. We muſt therefore, by all rules of induction and analogy conclude, that the ſun, being a body of flame, his effuſions of ſubſtance in the form of heat and light, muſt be ſupplied by a perpetual influx of proper fuel. This he elaborates into his own ſubſtance, and again ſublimates into light, which by the expanſive vigour his pabulum infuſes and ſupports, he propells beyond the orbits of Saturn and his ſattelites, to illuminate, cheriſh and invigorate all parts of the planetary ſyſtem. To anſwer theſe purpoſes, and to preſerve the ſun's uniform vigour and magnitude, not even an hundred comets each day, much leſs an odd comet at ſuch diſtant intervals would be an adequate ſuſtainment; we muſt therefore conclude, that an all-wiſe God, who at the Creation made every thing neceſſary for the preſervation of the Univerſe, and the perfection of all its parts, has provided all the bodies which compoſe it with ſuch powers, principles and qualities, as were adapted to their ſeveral functions, and has eſtabliſhed between them ſuch connection and intercourſe, as to contribute to their mutual ſupport and the general ſuſtainment of the material world, until the time he has appointed for its diſſolution; and with a beneficence and providential care, conformable to infinite goodneſs, has furniſhed each being with a ſuſtenance or means of ſubſiſting before he gave it exiſtence, by firſt creating, and conveniently placing its food to prevent failure or decay.

Thus Divine Providence, previous to the creation of man, made animals, vegetables, and all other beings neceſſary for his ſupport, and placed them conveniently for his uſe. Before he created animals he provided vegetables for their nouriſhment; he created water before fiſh, and earth before plants; in fine he created the ſun, earth and water previous to the animal and vegetable productions which are ſupported and cheriſhed by theſe elements. Is it then to be ſuppoſed, that theſe great elementary bodies, which thus nouriſh and preſerve the animal and vegetable world, are themſelves deſtitute of ſupport and nouriſhment, and debarred of all intercourſe, whence they may derive their vigour and preſervation? No, to ſpeak phyſically, they could not ſubſiſt for any time, if the loſſes they ſuſtain by their effuſions in favour of animals and vegetables, and by the conſumption of the fires in and about the earth, were not ſupplied by a conſtant flow of nouriſhment to repleniſh their ſubſtance and renew their vigour. The waſte or failure of theſe elementary bodies would immediately involve the decay and extinction of animals and vegetables, which they ſuſtain and enliven. To form therefore theſe bodies without a ſupport and renewal would be unprovidential and unbecoming an all-wiſe, all-powerful and beneficent Creator.

Doubtleſs therefore theſe great elementary bodies have inexhauſtible funds made for their ſupport, not only to ſupply the loſſes they ſuſtain by the ſupport of thoſe beings which depend upon them for ſubſiſtence, but alſo to ſupply their mutual loſſes in ſuſtaining each other. This is performed by a reciprocal intercourſe of their effuſions and influences, which aſſimilate to proper aliment for their mutual ſuſtainment. Thus we find our atmoſphere, that grand ſtore, which ſupplies us with inſpirable air, and which is equally beneficent to animals and vegetables; we find, I ſay, according to the obſervation of the ſagacious Boyle, that it is conſtantly ſupplied from the evaporations and exhalations of the earth, of the waters, and of the various beings they contain, as alſo by the ſtars and ſun, whoſe influences of light and heat, together with the evaporations juſt mentioned by the tremours, ſtorms and perturbations of this grand reſervoir, are digeſted, blended and elaborated for animal and vegetable uſes. Here are many and conſtant ſources to ſupply and preſerve the vigour and magnitude of our atmoſphere, a tribute, which it again repays, at leaſt to the bodies beneath it; to vegetables and animals, &c. it imparts the ſaline principle ſo neceſſary for their texture and conſtitution, with inſpirable air and electric accretions; to the waters it pays its tribute by the floods of rain it pours into their beds; and to the earth by the refreſhing ſhowers with which it bedues her ſurface. In theſe ſhowers the terreſtrial particles, which were before exhaled, return again pregnant with ſpirit and refreſhing powers to nouriſh and enliven the earth and her productions, and thus the evaporations and exhalations are repayed with nurturing, invigorating and inſpirable matter; ſo that a perpetual intercourſe ſubſiſts between the atmoſphere and the earth, the waters, and all the beings they contain, whereby they ſuſtain and preſerve each other by a mutual and general traffic of ſubſtance.

Theſe three great bodies are contiguous, and have a mutual intercourſe. But the ſun is too remote to partake of this commerce; and, altho' he is continually pouring his ſubſtance on us in a conſtant profuſion of light and heat, from his great diſtance, we cannot imagine how any exhalations or effuſions of theſe bodies can reach to him, to reſtore his loſſes and refund the quantities of his ſubſtance he ſo liberally imparts to them. It is well known, that a bit of antimony or red lead placed in the focus of a mirror will in a moment increaſe in weight by $\frac{1}{8}$. This addition of weight proceeds, according to the opinion of philoſophers, from its having gained ſo much of the ſolar matter; for it cannot proceed from air, as the effect will be the ſame if the focus be directed into an exhauſted receiver. Now if the ſun at this diſtance ſuffers in one moment ſuch a loſs of ſubſtance by a ſmall beam of his light, how much ſhould he have loſt by the ſame beam in the ſpace of a year? and if ſuch a quantity be effuſed thro' a circular area, ſuch as Villet's mirror above deſcribed of leſs than 22 inches radius, how prodigious a quantity muſt paſs during the ſpace of a year through a ſpherical ſurface whoſe radius is above 81 millions of miles, which is equal to our diſtance from the ſun? how much then for an hundred or a thouſand years? how much in fine from the creation of the world and again to its diſſolution? doubtleſs, the ſun has already emitted and may hereafter effuſe many million times his own quantity of ſubſtance.

If then comets were the only fuel deſtined to ſupply the effuſions and to ſupport the magnitude of that body, ſo laviſh of his ſubſtance as to fill a ſpherical ſpace whoſe radius is greater than the diſtance of the remoteſt of Saturn's moons, with ſuch plenitude of his luminous ſubſtance, that there is not in all that vaſt ſpace, except where an opake body intervenes, the ſmalleſt part or interſtice, even the ſize of a pin's point void of light, as we have ſeen in the firſt volume of this work, what a prodigious number of comets ſhould have been created for his conſumption during that interval? ſhould not, as we have ſaid before, but from a different conſideration, comets, inſtead of being a rare and ſolitary phænomenon, be more numerous than the ſtars? Theſe reflections might have induced Lemery, Boerhaave, and perhaps others to conclude, that the ſun, not being ſupplied with pabulum ſufficient for his waſte, did not really emit any part of his ſubſtance, but was ſimply endowed with a power of exciting and determining the fire of our atmoſphere in parallel rays towards us; but having confuted this opinion from the phænomena of the inferiour planets, and of the moon in and near conjunction, we cannot here adopt it, and ſuppoſe that the ſun wants no ſubſiſtence, becauſe forſooth philoſophers have not yet diſcovered or aſſigned any other pabulum but comets, which are entirely inadequate to his ſupport; on the contrary, however difficult it may be to determine his fuel, we muſt conclude from the reaſons alledged, that the bountiful Creator, who has furniſhed all other bodies with means of ſupport and nouriſhment, has alſo provided for this cheerful beneficent luminary an aliment proper and ſufficient to ſuſtain him, and has placed it convenient for his uſe and ſupport.

And if the ſtars be likewiſe ſo many ſuns, in the ſame manner effuſing their ſubſtance, as doubtleſs they are, (for how otherwiſe than by the emanation of their native light could they appear ſo ſplendid and vivid at diſtances ſo immenſe) to ſupply, as well thoſe ſeen by the naked eye, as thoſe whoſe diſtance is ſo prodigiouſly great, that although they equal our ſun in magnitude and luſtre, as allowed by all philoſophers, they are ſcarce rendered viſible by teleſcopes; to ſupply others, in fine, which may be as far beyond them, as they are diſtant from us, and all equally profuſe of their ſubſtance where ſhall we find comets, or any other fuel, proper and ſufficiently abundant? Shall we then ſilence curioſity, and pronounce it impoſſible? or ſhall we pretend, that they ſubſiſt differently from all other bodies in nature without pabulum or ſupport? The latter would be as contrary to all rules of philoſophyzing, as it would be contrary to nature: the former would be unbecoming the enquiring ſpirit of philoſophy, and repugnant to our idea of the creative power, and the axioms thence educed in the firſt lecture of this work. Even without recurring to a train of axioms, we may at once conceive, that the Power which gave exiſtence to thoſe prodigious bodies, and endowed them with their admirable faculties of warming and enlightening, which meaſured out their diſtances, and aſſigned their reſpective ſpheres of influence, was able to create, and really has created for them, a fund of nutriment proportioned to their conſumption, with the ſame wiſe and beneficent profuſion, wherewith all other bodies have been provided with ſuſtainment.

The exiſtence of this fuel being therefore inconteſtible, let us have recourſe to experience, to diſcover what muſt be its nature and mode of operation.

A perſon who ſits near a fire in very cold weather, will find the backs of his legs cold, tho' his ſhins be ſcorched. In the ſame manner a perſon ſtanding at a ſtove, will alſo feel one ſide cold while the other is warm. This proceeds from an influx of the cold air into the hotter place, which is more ſenſibly perceived, if one holds a candle at the door of a warm room, or ſpreads an handkerchief acroſs the fire place; for the flame, in the firſt caſe, and the cloath, in the other, will tend ſtrongly towards the heat, on account of the preſſure of the influent air. Hence the uſe of the tin plate which prevents the air from getting to the chimney, except by paſſing thro' the grate; for the current of air thus directed to the fire, at once enlivens it both by ventilation and by the elaſtic ſpirit it infuſes: hence alſo the uſe of bellows and air furnaces, whoſe powerful ventilation and copious infuſions, impart a vigour to fire capable of heating, fuſing, and refining metals. And even a candle flame, however feeble its heat and power of burning, is particularly invigorated at the ſurface by the influx of the ambient air, as may be perceived by a ſimple experiment; for hold a thread, or thin but uniform chip acroſs ſuch a flame, and the parts of either, which correſpond with the verge of the flame, will be found to kindle and burn previous to the intermediate part, where it might naturally be imagined the flame is moſt intenſe and powerful. Whence we infer an immediate proof of theſe two propoſitions, to wit, 1ſt, that the vigour of flame is reduced by digeſting its pabulum; and, 2dly, that it is on the contrary improved where the flame has an immediate intercourſe with the air; for the one iſſuing forth with expanſive force, the other preſſing into it by a natural propenſity, a conflict is produced between both, which irritates the verge, and there accelerates the conſumption of thin bodies. But, certainly, if the vigour of flame at the wick was not, according to former obſervations, diminiſhed by digeſting its food, its power would be at the centre more permanently ſtrong, at leaſt in communicating heat to denſe bodies; for there the repulſive reverberations, which produce the expanſive and centrifugal propenſity of heat and light, are in force and perfection, the effect of which appears from the encreaſe of heat in a ſmith's fire when thus concentrated by being ſpunged or ſprinkled with water.

All theſe inſtances ſhew the influx of air into fire or flame, whereſoever or howſoever either ſubſiſts. They alſo ſhew the utility of ſuch an influx; but, what is ſtill more, from Boerhaave's experiments on the roſemary plant, recited in our firſt part, and from univerſal experience it appears evident, that no body can ever aſſume the form of flame without a free acceſs and influx of air. No flame can ſubſiſt without air, for however ſtrong and lively before, it will inſtantly extinguiſh in vacuo. If, therefore, analogy be a rule which all philoſophers muſt obſerve; if no celebrity can authorize a philoſopher to depart from univerſal obſervation, and obtrude on the world arbitrary notions; if nature be ſimple and like unto herſelf, the ſun and the ſtars cannot ſubſiſt in a vacuum, but, like every other luminary and fire in nature, muſt be ſupported and enlivened by the perpetual influx of an ambient fluid. This fluid, from the preſſure of its more remote and denſe parts, muſt flow equally on all ſides with a centripetal force into the ſun; and in its ingreſs into that great furnace of nature, undergo all the operations of digeſtion and tranſformation mentioned in the beginning of this lecture, until it be perfectly ſublimated at the centre. Here the transformed ſpecies meeting from all ſides in conflict, reverberates to the ſurface with centrifugal and unimmaginable force, and thence iſſues forth on all ſides in a ſpherical flood of light.

What we here ſay of the ſun muſt alſo be applied to the ſtars. The immenſe ſpaces between them, would certainly be large and convenient ſtores to contain a ſufficiency of pabulum to ſuſtain and invigorate them all for any length of duration. Or, if the interſtellar ſpaces were too confined to contain a ſufficient ſtore of nutriment for all thoſe luminous bodies for any given time, could not the Omnipotent Creator have enlarged theſe ſtores of aliment, and extended them to a diſtance far beyond the remoteſt ſtars? Now if this immenſe extent, which may be conceived ten million, or ten thouſand million times greater than the diſtance of the remoteſt teleſcopial ſtar, be conſidered as the radius of a ſphere filled with proper nutriment for the ſun and ſtars, ſuch a body of ignutritive matter (if I may be allowed the expreſſion) would be an ample and convenient ſtore for the maintenance of all theſe luminous bodies for any given duration. All this is certainly poſſible and eaſy to that infinite Power, which has created theſe immenſe luminaries, and ſtill preſerves their magnitude and vigour with the ſame facility and by the ſame ſecondary cauſes, as he employs to nouriſh and ſuſtain other luminous bodies, leſs prodigious in ſize, but in nature, operation, and phænomena the ſame. Now this immenſe globe, which for the future we may call the *mundane ſphere*, compriſes the whole univerſe, and agrees with what Moſes calls the *firmament of the heavens*, in which the ſtars were fixed by the hand of the Creator.

This being conceived, let us now ſuppoſe ſuch a number of lamps or candles placed in our atmoſphere as there are ſtars in the firmament: or, to bring the compariſon more home, let the earth together with the atmoſphere be ſuppoſed all one body of air, whoſe radius may be about 4050 miles; let this aerial ſphere be ſet with ſmall bodies of flame, like the flame of a candle, to repreſent the appearance and ſtate of the ſtars in the heavens. Thus we ſhall have a miniature-repreſentation of the firmament beſet with the luminaries that enlighten and embelliſh it.

For in this vaſt globe of atmoſpheric air, each little flame would mould for itſelf a ſpherical vault of rarified air, which would flow from all ſides into the central flame, not by any attraction from within, but by the preſſure of the remoter air, which, to form an equilibrium, muſt neceſſarily flow towards the rarer parts to ſupply the perpetual conſumption and exhauſtion of air produced by the flame encloſed. In the ſame manner every ſtar in the firmament moulds for itſelf a circumſcribing vault, from all parts of which the celeſtial matter will pour in, to nouriſh the central luminary and furniſh it with fuel, which that fiery body conſumes, aſſimilates, and afterwards expends in effuſions of light.

If it be objected, that the celeſtial matter has not the ſame reſources and ſupplies from an intercourſe with other bodies, which our atmoſphere enjoys to repleniſh its loſſes and conſumption, then we may ſuppoſe this ſphere a million times greater; ſo great, in fine, as to be an ample ſtore for the maintenance of all the celeſtial luminaries for any given time: a thing, ſo conſiſtent with the wiſdom and power of God, cannot, certainly, be conſidered as beyond the reach of Omnipotence. He that formed the frame and machinery of a midge, has alſo formed that of an elephant; and He, who made the atmoſphere to maintain the bodies it inſpires and preſerves, could have made a ſphere of celeſtial matter, to nouriſh and preſerve the luminaries contained in the firmament. Nor do the nature of theſe two ſpecies of aliment differ more widely, according to our obſervations, than do the kinds of aliment, upon which the midge and elephant ſubſiſt. Our ſuppoſition, therefore, of a ſphere of ſuch ſidereal aliment, of a magnitude capable of ſupplying the effuſions of the ſun and all the ſtars, from the creation to the conſummation of the world, is perfectly conſiſtent with the attributes of the Creator, and analogous to his other works. However, it is not from its magnitude alone, that the firmament derives its ſufficiency to ſupply the immenſe effuſions of the celeſtial luminaries: analogy and obſervation of the wiſe œconomy of the Creator in the other parts of nature ſuggeſt another ſource of indefectibility, which ſhall be illuſtrated and eſtabliſhed in the following ſection.

SECTION IV.

Aſſimilative property of the ſolar pabulum a ſource of its permanence and ſufficiency. New proofs of the exiſtence and properties of that matter from Scripture and ſenſe.

ALL fires upon earth are continually fed and kept alive by a perpetual influx of air; and, from what we ſee, we are authorized to think, that were they ſupplied with fuel for ten thouſand years, they would be ſtill ſuſtained with air, without any failure or diminution of the atmoſphere. The reaſon is, becauſe the atmoſphere itſelf is perpetually ſuſtained and repleniſhed by the tribute it receives from all other bodies, whoſe evaporations, exhalations, &c. it aſſimilates to air. In like manner our ſun is ſupplied with influent matter from his ſpherical ſpace, which is ſuſtained and kept full by the inward preſſure of the vaſt mound of celeſtial matter or firmament, by which his ſpherical ſpace is encloſed. And theſe effuſions he again refunds by emanations of light equally abundant, which, not only invigorate nature, and meliorate the crude matter of the firmament for his nouriſhment; but alſo repleniſh his ſtore of food: theſe emanations being themſelves aſſimilated to the nature of the celeſtial matter, in the flood of which they blend and are abſorbed. Thus a mutual intercourſe ſubſiſts between the celeſtial matter and the luminaries it ſupplies, whereby they reciprocally ſuſtain each others quantity and vigour, as do neighbouring bodies upon the earth.

Hence then no difficulty ariſes from the immenſe magnitude of the ſun: immenſe, I ſay, for certainly the magnitude of that beneficent body muſt be prodigiouſly great, which at this diſtance warms and cheriſhes the earth and her productions, cheers her ſeaſons, revives her beings, and, by the power of its expanſion, diſeminates its effuſions of light and heat to bodies and ſpaces vaſtly more remote. The radius of the ſun is computed to be 152 times that of our earth: and we have already ſeen, that this great body is compoſed of liquid flame. The radius of the moon's orbit is only

60 times the radius of the earth. Now imagine a globe of flame which would fill the ſpherical ſpace of the lunar orbit, how many earths, comets, and planets would it not ingulph, being 21,6000 times as great as our earth! The ſun, however, is vaſtly larger, and would have but a pitiful meal of all the comets and planets within the knowledge of man, being within 3 and 4 million times greater than the earth; a magnitude neceſſary, no doubt, for cheriſhing ſaturn and his ſecondaries, and for illuminating ſpaces beyond his ſatellites. Such then is the great focus, wherein the Creator has collected and ſtored up that part of the primeval light, which he had deſtined for enlivening animals and vegetables, for fertilizing the earth and her productions, in fine, for illuminating and invigorating our planetary ſyſtem until the end of time.

But, however imenſe this body of fire, how ſoon would it be exhauſted by the continual effuſions of ſubſtance, which this luminary by its expanſive vigour pours forth, unleſs it were conſtantly ſupplied with nutriment to preſerve its magnitude and vigour! And how vaſtly inadequate is the poor ſuſtenance hitherto aſſigned by philoſophers to preſerve and invigorate this body of fire! The inteſtellar ſpaces alone are large enough to be the ſtores of his nutriment: and they are replete with the matter of the firmament, in which the ſtars and ſun are fixed and perpetually ſuſtained by the effuſion of this celeſtial matter from the denſe mound that circumſcribes the rarified ſphere formed by each luminary. Theſe infuſions of celeſtial matter the luminary repays by emanations of light, which emanations the body of alimental matter aſſimilates anew to its own form and nature.

Thus an ox elaborates and aſſimilates graſs and vegetables to the form of fleſh, and repays the earth with manure to bring forth again what he conſumes; thus vegetables, alſo, aſſimilate the terreſtrial juices to their reſpective forms, and again beſtow on the earth their leaves, branches, ſtems, trunks, and, at length their whole ſubſtance, which turns to ſoil, and becomes once more a nutrimental ſubſtance for the vegetable kind. By a little reflection on the production, growth, exhalation, decay and fall of the animals, vegetables, and foſſils that are nouriſhed and ſuſtained by the earth, air and water, we ſhall eaſily perceive, that theſe elementary bodies ſuffer no loſs of ſubſtance by the beings they ſupport; but that all theſe beings reſtore to theſe elements an ample equivalent for what they receive. We ſhall, however, give another inſtance of this aſſimilating power, whereby one body transforms another into its own nature and form.

A wildin or crab tree will aſſimilate the juices of the earth, which it imbibes, the air it inſpires, and the light it abſorbs into branches, leaves and fruits of its own nature. Now if this be made a ſtock, and thereon be ingrafted ſcions of various kinds, for inſtance, of apple and pear tree, they ſhall grow, and after a while through that ſour ſtem bring forth ſweet fruit according to the nature of the graft. This is certainly an imperial inſtance of the aſſimilating power in body; however, on reflection, we conceive it eaſier for the graft, when thoroughly knitted to the ſtock, to aſſimilate the juice, which has been there elaborated and digeſted to a vegetable nature, than to concoct and aſſimilate the crude juices immediately coming from the earth. But, let this be as it may, it is plain, that the preſervation and proſperity of the animal and vegetable kingdoms depend on their aſſimilating powers; and perhaps the ſame may be ſaid of the foſſil kingdom; for we find that water is ſo ſtrongly impregnated with the mineral, thro' which it flows, that whatever it is applied to ſhall be affected with the qualities of that mineral: whence the uſe of mineral waters. In the county of Wicklow there is a copper mine, whoſe waters change ſheets of iron into copper. Rain water alſo carries with it a prolific nature, which no other water is poſſeſſed of: the reaſon is clear, the atmoſphere receives the exhalations, perſpirations, and exudations of foſſils, animals and vegetables, as well as of earth: theſe it elaborates, blends and aſſimilates to its own nature: the waters of the clouds therefore deſcend teeming with theſe rich ſpoils to fertilize, refreſh and revive the earth and her productions. In ſhort, we find not a ſingle body independent of, or exempt from this general commerical intercourſe, which ſubſiſts between natural bodies, whereby they mutually ſuſtain each other thro' the aſſimilating faculty, with which the Creator has endowed them to preſerve the powers, productions and operations of nature for ſucceeding ages; can we then ſuppoſe, contrary to this invariable and univerſal law, which we experience in ourſelves, in animals, vegetables and foſſils, and even in the great elementary bodies of nature, all which nouriſh and ſuſtain each other by their natural intercourſe and traffic of ſubſtance, that the ſun ſubſiſts ſolitary and unſuſtained, without intercourſe or exchange of ſubſtance between it and any neighbouring bodies? No, the ſun is ſubject to this univerſal law, and by analogy muſt communicate with ſome neighbouring body to receive, aſſimilate, and refund his vaſt effuſions. This body therefore muſt be the ſtore or magazine, which is to ſupply his perpetual and immenſe effuſions, and can occupy no leſs a place than the interſtellar ſpaces, which alone by their extent and ſituation are ſufficient and convenient for the purpoſe. Is it not ſtrange then, that philoſophers, who profeſſed the ſimplicity of nature, and the laws for philoſophizing by induction and analogy, ſhould have pronounced thoſe vaſt interſtellar ſpaces to be vacuums or blanks in nature, without food or nouriſhment for the ſun or ſtars, and without fluid or medium to perpetuate the planetary motions, as if fire could naturally ſubſiſt without fuel, or motion be phyſically continued without impelling matter! Neverthelefs, the heavens muſt be emptied * by philoſophers to give a ſcanty morſel paſſage rather to tantalize than feed our generous luminary. But the truth is, this was a doctrine collected from ſome obſcure notions of the old atomic philoſophers,† which the great Newton propped up with mathematic calculations, without inquiring into its reality or conformity to nature, as we ſhall ſhew in a ſucceeding lecture.

We have then in this lecture educed from every ſource of phyſical knowledge, that there is in the heavens a ſpecies of matter diſtinct

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* *Newton's Op.* 28. *q. And therefore to make way for the regular and laſting motions of the planets and comets, it is neceſſary to empty the heavens of all matter, except perhaps very thin vapours, ſtreams or effluvia ariſing from the earth, planets and comets, &c:*

† *And for rejecting ſuch a medium we have the authority of thoſe the oldeſt and moſt celebrated philoſophers of Greece and Phenicia, who made a vacuum and atoms, and the gravity of atoms the firſt principles of their philoſophy, tacitly attributing gravity to ſome other cauſe than denſe matter, &c.*

from light, in which the ſun and ſtars are immoveably fixed, and by whoſe infuſions theſe luminaries are ſuſtained; we have proved the ſun to be a body of flame, and flame we have ſhewn to be a compacted light, as is evident from the concentration of ſolar light into flame by a mirror. Now ſcripture confirms all theſe concluſions, it relates (Gen. 1. c. 1. v.) that the Creator made the *heavens and the earth*, *i. e.* the matters out of which both were formed; for the ſecond verſe declares that this chaotic heap of created matter was not yet conſtructed into its deſtined form, *and the earth was without form, and darkneſs ſat upon the deep.* The inſpired author then relates the creation of light ſubſequent to the creation of the chaotic heap, to warm and vivify the dark rude matter, of which the latter was compoſed: *and the Lord ſaid let there be light, and there was light.* The matter of light however thus created, was at firſt diffuſed over, and blended with the other matters before produced, until *the Lord divided the light from the darkneſs*, and collected this laſt fluid into ſeparate parcels. For the ſeparation here expreſſed cannot mean a ſeparation of mere abſtract qualities, but a ſeparation of the two ſpecies of matter, endowed with theſe qualities, and capable of being divided from each other. Now if this light was compacted into two or more bodies, as the ſeparation implies, and, as we know from experience to have been the caſe, muſt not the bodies reſulting from this compaction be bodies of flame? The ſun and ſtars therefore, which are evidently the collections of light thus formed, muſt be bodies of flame, ſo that ſcripture confirms this eduction from experience and reaſon.

According to the ſame text alſo and to reaſon, the luminous matter laſt created muſt be different in nature and ſubſtance from the primordial dark matter. Of this latter then was made that firmament of the heavens, in which the ſtars were placed: the neceſſity of which from phyſical arguments we have already educed. For the heavens, with the creation of which Moſes begins his ſublime narrative, *in the beginning the Lord created the heavens*, cannot be pretended to be a mere nothing, *i. e.* a vacuum: Neither can that firſt object of creation be confounded with the matter of the earth from which the heavens are expreſsly diſtinguiſhed by the ſacred penman. Firſt of all, therefore, the Creator brought into being the celeſtial matter, which was to be the greateſt of his works, to conſtitute the firm boundary of nature, and to be the exhauſtleſs ſource of vigour and ſuſtainment to all the luminaries that enlighten, cheriſh and animate the univerſe.

Shall the looſe opinions then of an Heathen philoſopher, induce us to ſtrain the ſacred text and pervert its meaning? Shall they induce us to refuſe to the Creator any glory from the greateſt and moſt ſtupendous of his works, *the firmament of the heavens?* No, let us weigh well the emphaſis laid on the creation of the heavens throughout this inſpired narrative and other parts of holy writ, and we ſhall find it hard to be perſuaded that theſe heavens are only a vacuum, *i. e.* a nothing. But though revelation was ſilent, our own eyes might make us call in queſtion the truth of this tenet; for the firmament at night, when the atmoſphere is clear, appears as if made of ſolid jet, and in the day from the light of the atmoſphere, it aſſumes the appearance of the concave ſurface of a beautiful azure ſphere; ſo that ocular evidence concurs with revelation, reaſon and experience in the ſupport of our concluſion: but of this more ſhall be ſaid when we come to treat of the firmament in particular.

For the preſent, however, we appeal to ſenſe, if the ſun and ſtars do not appear fixed in the ſky or celeſtial matter, juſt as the candle flames ſhould do, were they placed, as we have already deſcribed, in different parts of the atmoſphere. Theſe little flames, we have ſeen, would form for themſelves each its own vault of rarified air flowing into its central flame, through the preſſure of the more denſe and remote air, to inſpirit and preſerve it. In like manner the celeſtial matter, which ſurrounds each ſtar, forms a rarified vault of that matter, which is conſtantly flowing in to nouriſh and preſerve the light, magnitude and vigour of its central luminary, being preſſed from abroad by the denſe mound with which it is circumſcribed; and, as in the atmoſphere, there would be as many vaults of rarified air as there are lights ſuppoſed, ſo alſo in the heavens there ſhould be as many ſpheres of rarified matter as there are ſtars, the magnitude of each ſphere being as the magnitude of the luminary ſtationed in its centre.

It will be objected, that every candle or lamp requires ſomething beſides the air to ſupport or ſuſpend it, ſo that pedeſtals ſhould be aſſigned to ſupport the ſtars. This objection is eaſily removed, if we conſider that a rocket, when fired, ſhoots forward by the reaction of the air againſt the protruding flame it emits; ſo that, if two rockets were joined together vertically, and thus fired at each end, they ſhould remain at reſt; becauſe the actions or cauſes of motion being equal ~~and~~ contrary, would deſtroy each other's effects. Conſequently, if a ſpherical body of cork, paſteboard, or ſome ſuch light matter were ſet all round with rockets vertically oppoſed and raiſed on the top of a high pole or ſpire, all being fired together, the fiery globe would remain at reſt in that point of the atmoſphere. And this would be the caſe tho' the pole were taken away, ſome trivial allowance being made for gravity. Thus we have a repreſentation of the ſun, or of a ſtar at reſt in the heavens without any other ſupport, except the equal preſſure of the celeſtial matter flowing from all ſides of the ambient ſpherical ſpace and the reaction of its own emanations againſt this matter in all directions.

The force of this action may be rendered ſenſible by the experiment we have mentioned of a wheel's being turned by a ſtream of electric matter iſſuing from a point of the prime conductor, when impregnated; for if another ſtream of the ſame matter was made to act upon the wheel in an oppoſite direction, being equal, the ſtreams would deſtroy each other's effect, and the wheel would remain at reſt and in equilibrio between both. Now we have ſeen, in the firſt part of this work, that the ſun effuſes its ſubſtance in the form of light, by an expanſive vigour proper to all bodies of a fiery nature, but prodigiouſly great in him, who ſends his effuſions beyond the diſtance of Saturn's moons; how powerfully then muſt theſe emanations act againſt any ſurrounding body or medium, ſeeing the force wherewith the electric emanations act upon the wheel, or thoſe of the rocket againſt the air! but with regard to the ſun, theſe emanations act from his ſurface *in orbim*, in all directions with centrifugal propenſity; therefore his action is equally forcible from all parts of his ſurface, which is one cauſe of his reſt; the ſecond is the equal preſſure of the celeſtial matter, flowing on all ſides with convergent and centripetal propenſity to nouriſh and ſuſtain him. From both cauſes, therefore, the ſun and ſtars may remain imperturbably fixed and perpetually ſuſtained without any additional ſupport.

This explanation exactly correſponds with what we can gather from the ſcriptures of the fixture of the ſun and ſtars: nor could that phœnomenon be otherwiſe phyſically explained, according to the laws of rational analogy founded on experience. Therefore this effect is a new proof of a ſidereal aliment, which at once nouriſhes and fixes theſe luminous bodies; wherefore a vacuum can by no means be admitted. It is even ſurpriſing how ſuch a ſuppoſition has ever prevailed, being not only unſupported by experiment or analogy, but directly contradicted by both; for no body within the reach of experience is found to move or ſtand upon nothing, and no fiery body of which we can be competent judges is ſeen to ſubſiſt without a conſtant ſupply of fuel, ſo that the admiſſion of a vacuum is contrary to Newton's fourth rule of philoſophizing.

From the whole of our arguments therefore, which have been founded on experiment, common experience, analogy, the Newtonian rules, and the authority of ſcripture, we conclude, that the ſun and ſtars are bodies of flame or compacted light, emboſomed in the immenſe ſphere of celeſtial matter, which conſtitutes the firmament of the heavens and the fuel of the ſtars, and conſtantly ſupported by the double action of their own emanations and the infuſions of the firmament. Theſe infuſions are gradually elaborated into a ſimilitude with the ſolar ſubſtance, and when perfectly aſſimilated, are again expended in effuſions of light, which theſe luminaries, by an expanſive property eſſential to all fiery bodies, ſend forth anew into the vaſt ſpherical ſpaces which they reſpectively illuminate, as the ſun does this, wherein the earth and planets move round him, and which is bounded by that concave ſurface of the firmament or celeſtial canopy we behold over and around us beſpangled with ſtars.

LECTURE IX.

A Survey of the Firmament and its Properties.

SECTION I.

Neceſſity of a bounding Frame to encloſe the Univerſe. A philoſophical Tour throughout the Firmament and fixed Stars.

THE power and wiſdom of the bountiful Creator, from whom we derive all that we have and all that we are, are magnificently diſplayed in the works of the creation. The machinery of nature is the work of Omnipotence: her order and ſymetry beſpeak preſcience and deſign, and her perfection and preſervation indicate providential care. Every thing in the univerſe, in ſhort, excludes the notion of chance or jumble, and proclaims one univerſal law throughout all nature, *viz. the fitneſs of things.* This principle is the baſis of phyſics, the foundation of our axioms and of our method of philoſophizing: it is the light by which we hope to explore the ſecrets of nature, and the ſource of whatever diſcoveries we have hitherto made. To it we are indebted for diſcovering the real mode of light's motion and propagation, the continuity of that ſubſtance and the cauſe of tranſparency: to it, alſo, we owe the diſcovery of the nature and properties of the elaſtic matter, a ſubſtance ſo well adapted to be the baſis of qualities and of medicinal virtues, and ſo efficacious in preſerving all the powers of nature. For it is by the operations of this active ſubſtance that the brooding ſeaſons bring forth their annual productions, and the various generative ſpecies procreate their reſpective offspring from generation to generation; and thus preſerve all the beings of the creation throughout ſucceſſive ages, until they are annihilated, or otherwiſe interrupted by the power, which gave them exiſtence. It is by the conſiſtency of this ſubſtance alſo, that lively powers are joined to inert matter, and admirably tranſpoſed from body to body.

Now if we examine the ſeed of vegetables, we diſcover this elaſtic matter confined within a ſhell, or a coat of firm matter in the form of an unctuous or nutrimental ſubſtance proper for the conſervation of the generant part which it contains. The ſame may be ſaid of the eggs of animals; and, perhaps, there is not in nature a being that propagates, whoſe rudimental ſpecies are not incorporated and wrapped up together in a ſhell with this conſerving matter to nouriſh and cheriſh them, and by a genial heat to quicken and vivify them in due ſeaſon, according to that Almighty mandate, viz. *that each ſhould bring forth in its kind.* This ſhell does not form the fœtus, but is neceſſary to compact the ſeminal ſubſtance, and prevent its diſperſion by the expanſive force of the light contextured in the elaſtic matter, in which it is conſerved. For without a ſhell the ſeminal ſpecies could not be collected and ſtored up together, but would be diffuſed throughout the parent's body, and thus loſe its virtue and efficacy in the procreant parts: wherefore every generative being has its proper matrix to preſerve and nouriſh the rudiments of its offſpring. We might now eſtabliſh ſome analogy between theſe matrices of generation, and the chaotic heap or egg of nature produced by Omnipotence in boundleſs ſpace, which contained inert and active matter, blended together to meliorate and prepare theſe original rudiments or principles of nature for forming the various beings of the univerſe. But independently of ſuch analogy, if the powers of nature were not confined within a ſhell, they would be diffuſed thro' infinite ſpace, and her ſcattered principles would become uſeleſs for want of that immediate intercourſe, by which they ſubſiſt, mutually ſuſtain each other, and preſerve that equilibrium, whereby theſe contending principles actuate the great machine of the univerſe.

We cannot conceive a machine without a frame to keep its parts together. Otherwiſe its principles of action and moving powers not retaining their ſtated places could not poſſibly anſwer the end of their deſtination. For inſtance, a watch or mill muſt have its frame to keep the principles of action and centres of motion in their reſpective places, and to preſerve their reſpective poſitions and diſtances. For if an axis only ſtirs from its centre, or a centre, a ſpring, or even a cog is diſplaced; if any part eſſential to the machinery be removed or damaged, the whole is diſordered, and the ſyſtem becomes uſeleſs. Wherefore a frame is neceſſary for every piece of machinery or organized body, to preſerve the ſites and poſitions of the principles that act, and of the parts that are ſubſervient to each other. Hence a vegetable muſt have its bark or ſkin to cover it entirely, leſt its circulating juices ſhould waſte or loſe their way. Hence, alſo, an animal muſt have, not only a ſkin and tubes to confine and conduct its fluids, but muſt alſo have a firm frame to preſerve its dimenſions and collect its powers to their places, ſituations, and principles of action: otherwiſe the organization is deranged and diſtorted by the force of its own powers improperly exerted, and its principles diſperſed; and the intercourſe and circulation being thus loſt, all parts languiſh, and the ſyſtem fails. Even an egg or a nut, if its contents be diſturbed, or any part moved from its place, will loſe procreancy, as if generation depended, not only on the ſeminal principle and ſubſtance which the ſhell contains, but alſo on the organization of its parts. And in the egg, is it not the expanſive vigour of the *genial lumen*, more abundantly compacted in the ſeminal ſubſtance of the animal in the oppoſite ſpecks or poles of the yelk, that operates by the heat of the hen, and gives the egg an oblong form, before its expanſion is corrected by the hardneſs of the ſhell? Whence we ſee the neceſſity of a teſtacious ſubſtance to bind the whole together.

And if this be ſo with the feeble principles of minute and trivial bodies, how much more neceſſary is a bounding frame to the machine of the univerſe, whoſe vigorous principles actuate all nature, and perpetuate her prodigious and unremitted operations? If theſe principles were unconfined, and ſuffered to diffuſe and waſte in infinite ſpace, they would loſe all energy, order, and operation; as gunpowder, when unconfined, produces but a vain and feeble flaſh, but, if duly confined and compreſſed, exerts an irreſiſtible force.

From analogy, therefore, and the *fitneſs of things*, muſt not the machine of nature have its frame or teſtaceous boundary to keep its principles in their ſtated places; to prevent their diſperſion and a waſte of their powers in infinite ſpace; to confine their emanations, and to preſerve that intercourſe of their ſubſtances, on which her operations and productions depend? Since theſe operations are perfect and regularly produced in their ſeaſons, we muſt conclude, that the principles are properly ſtationed, and their powers confined and duly ſuſtained by a ſettled intercourſe and orderly circulation of ſubſtance: all which require a frame as neceſſarily, as does the regular action of a watch, or animal, or the generativeneſs of an egg. Yes, we muſt unavoidably conclude, notwithſtanding contrary hypotheſes, that all the machinery of nature is framed in, and the whole ſyſtem encloſed within a *firmament*. This great ſyſtem of nature, for diſtinction ſake, we ſhall call the *mundane ſphere*, or egg of nature, which may either be at reſt, or in motion, in infinite ſpace according to the Creator's will: and as *Noah's* Ark moved or reſted on the waters of the deluge, without diſturbing the ſtructure or poſition of its different appartments, ſo the numerous and prodigious vaults of this mundane ſphere, with their reſpective ſuns and ſyſtems of planets, retain their relative places, poſitions and magnitude conſtantly and invariably. Each of theſe vaults or ſpherical ſpaces, is conſtantly filled with the effuſions of its peculiar ſtar, juſt as we have ſeen (L. vii. V. I.) the ſolar ſphere conſtantly replete with his continuous and ſucceſſive emanations; and each luminary is fixed and ſuſtained by the action of its light againſt the alimental medium flowing in for its ſupport.

But to begin with the ſun; his conſtant emanations of ſubſtance warm, qualify, and aſſimilate the celeſtial matter that flows from the firmament. The nearer, therefore, to the ſun, the more rare this ſidereal *pabulum* is, and the more diſtant, the denſer and colder it becomes; *i. e.* in every part of ſpace theſe qualities of his pabulum are inverſely as the oppoſite and correſponding qualities of his luminous effuſions; ſo that if we ſhould make a journey from the ſun thro' the heavens in a line toward *Sirius*, which is allowed to be the the neareſt of the fixed ſtars, being the firſt in magnitude, the farther we recede from the ſun, the leſs denſe and ſtrong will be the light and heat of his effuſions, and the more denſe, dark and cold his alimental matter will be found, until we go half way to Sirius, where his light and heat vaniſh, and his pabulum is in the higheſt degree of intenſity and frigidity. For that part of the heavens being equidiſtant from both theſe luminaries, which warm and qualify the ſidereal aliment, and ſo remote from either, as ſcarcely to partake of their influence, will retain its native darkneſs, cold and denſity in the higheſt degree. Again, on the other ſide of this barrier as you approach nearer to Sirius, theſe qualities diminiſh on account of the increaſe of his light, which tempers and meliorates this alimental matter. Still nearer to him, it is further tempered and heated for his nouriſhment, and flows in to preſerve his vigour and magnitude as air does into flame: at length, arriving at Sirius, you find him fixed in the centre of his own vaſt ſpherical ſpace, which he warms and illuminates by his effuſions, in the ſame manner as the ſun enlivens and cheriſhes his peculiar ſphere, and the ſyſtem of planets that ſurrounds him.

We ſhall not here examine whether Sirius or any other ſtar has a ſyſtem of planets revolving about him, but conſidering him as ſolitary in his place, will make ſome obſervations on his ſtate and mode of ſuſtainment, We find him then fixed like another ſun in the centre of the ſpherical ſpace he illuminates by the preſſure of his own effuſions acting on the ambient matter that preſſes in to nouriſh him, as air does into fire; not through any attraction in the fiery body, but on account of the conſumption of matter that enters it, and the rarifaction of that which ſurrounds it. For to form that equilibrium which all fluids endeavour to preſerve in the ſpiſſitude of their ſubſtance, and to fill equally and uniformly all the ſpace it occupies, the remoter part from the luminous body, being more crouded as to place, and more denſe in ſubſtance than the rarified part next the ſame body preſſes in to reſtore the equilibrium. This preſſure alone might cauſe the matter next the luminary to enter that body, but does it more effectually, as that which enters is conſumed and refunded in a new form.

Thus the luminary may be conſidered as a perpetual rarifier of that matter which is always flowing into it, with the rapidity of air into an exhauſted receiver, to which it gains acceſs: wherefore the motion of this pabulum to the luminary, as well as that of air to a fire, is owing to the conſuming power of theſe bodies, whereby a vacuum is perpetually conſtituted; but is not to be aſcribed ſimply to the rarifaction of the influent matter. For if no air was conſumed by fire, the body of air immediately ſurrounding it, would from heat acquire ſuch a degree of expanſion, as would cauſe it to react and preſs back againſt the remoter air more powerfully than the exterior air could preſs on it; ſo that in that caſe the current would be rather from the fire than towards it. Conſequently, as experience ſhews the current to be towards the fire, we muſt allow a conſumption of air, which like food to an animal, is neceſſary for its ſuſtainment and the preſervation of its vigour and magnitude; for prevent the intercourſe of air with flame, and it ſhall dwindle and die away, as would any animal when deprived of its food. So that in all beings we ſee the oeconomy and providential care of Divine goodneſs diſplayed in the abundance of food conveniently placed for their ſupport and preſervation. And this alſo proves the truth of our inveſtigation of material agents to actuate nature; for, altho' all beings exiſt in the omnipotent Creator, yet we ſee their exiſtence and utility depend on the material nutriments he has prepared for theſe bodies and its convenience, which in fact is no other than the bodies themſelves, their intercourſe and the influence they have on each other; which in a word conſtitute the whole frame and machinery of nature, its beings and powers.

Hence then the neceſſity of an influent current of air to flame, hence the reaſon why air ſhould flow into a room or ſpace where a fire, a candle, or animals are placed that conſume it, and hence alſo it appears that a juſt equilibrium is ever ſuſtained. For if the air or pabulum near the luminous body is more rare, reciprocally the luminous effuſive matter is there more denſe, &c. *vice verſâ*, ſo that in all parts of the circumambient ſpace, an equal ſpiſſitude of ſuch ſubſtance is ſuſtained by the influent and effluent matters; for the luminous body tho' it conſumes the alimental matter does not annihilate it, but digeſts and aſſimilates it to its own nature, and changes it into light which it then emits and propells, according as it takes in more nutriment. This mutual intercourſe between the influent and effluent matters, ariſing from the power of fiery bodies to receive, change, and again propel the ſame ſubſtance in a different form and direction, produces a perpetual motion and traffic of ſubſtance between the great principles of nature, and an equilibrium between their powers. There is then between theſe celeſtial luminaries and the firmament, wherein they are thus fixed, the ſame ſuſtaining intercourſe as ſubſiſts between the terraqueous globe and its atmoſphère, by which both they and all earthly bodies are preſerved. And no doubt, this latter intercourſe between the ſubaltern principles of nature, takes its riſe from that of the grand and primary principles of nature, which fill, pervade and rule the whole creation. And to render this theory more general, from the reaſons ſet forth throughout this and the preceding lectures, and what we experience in nature, we have room to conclude, that the pabulum of every fiery body, be it a fluid, as air and oil, or reducible thereto by heat, as wax or tallow in a candle or lamp, &c. when conveniently placed, muſt be in a continual flow to the conſuming body, directly as the effuſions of that body in the form of light are in a conſtant flow from it. If the effuſions be conſtant and uniform, ſo muſt the infuſions of its pabulum; if the former be great or ſmall, ſo muſt be the latter; and not only the flow of the infuſions is conformable to that of the effuſions, but the quantities of the influent and effluent matters are always proportional, and in any given time muſt be the ſame, effects being as their cauſes; for the flame is but an elaboratory, which annihilates not, but transforms its food, and then excludes it in luminous emanations. Hence a clear proof of the neceſſity of a ſolar pabulum in the form of a fluid ſurrounding him on all ſides, and ſupplying matter for his perpetual effuſions. Hence alſo a proof, along with others hereafter to be given, that the quantity of matter in the univerſe is the ſame now as it was when firſt bodies were created and formed; for it is not leſſened by conſuming bodies or fires, which effuſe in proportion as they receive. And their effuſions periſh not: for in the laſt lecture we have ſeen that the ſolar emanations being propelled by him, and preſſed into the fund of celeſtial matter, are transformed by it: now why ſhould not the one have an aſſimilative power as well as the other? the fitneſs of things requires it, to foſter and actuate the vigour of bodies, whether firm or fluid, whether animate or inanimate, to cheriſh them, to excite an active propenſity, and to generate a ſucceſſive cauſe of *equilibrium* in the powers of nature. This equilibrium proceeds from an equality of power and efficacy in the oppoſite principles of nature, which being equal and contrary, are ever undoing each other's effects. It compels the the parts of any fluid occupying a given ſpace to diſpoſe themſelves ſo as to produce every where an equal quantity of ſubſtance, ſpiſſitude and vigour; it is the ſource of the various changes in the conſtitution of natural bodies, of the viciſſitude of the ſeaſons, of the alternations of day and night, and in fine of all phyſical operations.

For brevity, let us now ſuppoſe ourſelves to have already paſſed from the ſun thro' the prodigious mounds of celeſtial matter that emboſom and nouriſh the ſtars, until we come to a ſtar of the third magnitude, where being now ſtationed, we are equidiſtant between the ſun on one ſide, and ſtars of the ſixth magnitude on the other. And hence again travelling as before through the regions of the firmament, to wit, its ſidereal vaults and vaſt mounds of celeſtial matter, let us continue our progreſs, until we arrive at the dark denſe mound ſurrounding a ſtar of the ſixth magnitude, or one of the remoteſt viſible to the naked eye. And here let us make a ſtand as before, to view the ſurrounding canopy embelliſhed with ſtars. The ſun we find on the one ſide now appears a ſtar of the ſixth magnitude; and the teleſcopical ſtars on the other ſide now aſſume the magnitude and brilliancy of ſtars of the firſt, ſecond, third, &c. magnitudes, according to their reſpective diſtances from our preſent ſtation. How many ſtars of different claſſes there may be in this or any other direction, or to what extent they are continued, is a queſtion unanſwerable and uſeleſs, except to fix our attention on the works of Omnipotence, and therein to admire, praiſe, and glorify our God and Creator. We muſt content ourſelves with concluding, that on this and every other ſide, until we reach the laſt boundary or adamantine ſhell, which confines all material nature, there are as many ſtars as the Creator ſaw it meet to form to qualify the celeſtial matter, to embelliſh the heavens, to fix celeſtial marks for aſtronomers, to determine the motion and periods of the planets and the meaſure of time by, or in fine to fill the minds of men with awe and admiration of the power and glory of an Omnipotent Creator.

Leaving this queſtion, then, to be diſcuſſed by others, we arrive at length at the remoteſt of the teleſcopcial ſtars. Here no more ſtars are to be met with in that direction; we find now before us the celeſtial frame or firmament which encompaſſes and ſets limits to all material extenſion. The thickneſs or depth of this great barrier between bounded and infinite ſpace may be equal to the diſtance between any two ſtars of different claſſes, but its denſity is far greater than that of the medium between the ſtars, on account of its greater diſtance from any rarifying luminary. The deſtination of this bounding ſhell of nature and of the partitions of celeſtial matter, beſides that of nouriſhing and fixing the ſtars in their reſpective places of the firmament, is to hem in the powers of nature, and to reſiſt, bear down and confine the expanſive vigour of thoſe luminaries: for otherwiſe, like our ſubterraneous fires that vent their raging torrents from volcanos, thoſe celeſtial fires would burſt forth on all ſides, and ſpend their ſubſtance, vigour and efficacy in an infinite void. Theſe firm boundaries are therefore neceſſary to prevent the waſte and loſs of the ſolar and ſidereal effuſions in infinite ſpace, to confine its meliorating influence to the beings of nature, and to fertilize the earth and planets, to render prolific the animal and vegetable kingdoms, and to qualify the celeſtial matter for ſidereal nutriment; whereby a mutual exchange of the celeſti- and ſolar ſubſtances is eſtabliſhed between the firmament and its luminaries, the primary agents and ſources of material powers, whoſe oppoſite qualities, light and darkneſs, heat and cold, are, as it were, ever contending for a maſtery over each other within this ſhell of nature, or in perpetual ſtruggle for a balance. By this ſhell alſo theſe powers and mean-ſprings of nature are fixed and their vigour continued to ſtimulate and preſerve the planetary motions: wherefore this extreme and univerſal boundary of material and limitted ſpace may be called the ſhell of nature, or boundary of the mundane ſphere. And here we cannot but admire the invention and ſagacity of the Egyptians in the hieroglyphick repreſentation of their god Eneph, or creator of the world; which is an human figure with an egg coming out of its mouth: an emblem, which with chriſtians may ſignify the word of god, which was god *by whom all things were made, and without whom no thing was made.*

Now let our imagination paſs the limit of corporeal exiſtence, and ſtanding, in idea, on its convexity, let us turn our conſideration to boundleſs ſpace, which is void of ſky, ſtars, atoms, clouds, light, or any material ſubſtance; for all ſuch material beings are confined within this boundary of the mundane ſphere. Tho' immenſe the regions, through which we have paſſed to come to the boundary of material nature; tho' this mundane ſphere be in compariſon to the earth greater than is the earth itſelf in reſpect to a grain of ſand; yet this ſtupendous ſphere is not as a grain of ſand, but rather as a mathematical point in infinite ſpace, which is occupied by the omnipreſent majeſty of the Creator.

But in order to form ſome more determined idea of infinite ſpace at the point of this mundane ſphere, whereon we now imagine ourſelves ſtanding, let us conceive two tangent lines drawn rectangular to each other, as if horizontally, ſo that a line drawn vertical to them would upon the earth determine the Zenith and Nadir; but where we now ſuppoſe ourſelves the caſe is different, for no ſuch lines drawn in boundleſs ſpace can mark a Zenith or Nadir, becauſe theſe terms imply a point, as it were, on ſome ſurface above and below; but here every ſuch idea is precluded, for travel for all eternity along any of theſe lines, and you meet not as from the earth a bounding ſky, or with any other limit or barrier, all ſuch ideas being inconſiſtent with infinite ſpace.

But in compariſons of this kind mathematicians muſt be ſilent and wave all calculations, as there can be no ratio between bounded and boundleſs ſpace, even though the magnitude of the former were taken at the utmoſt limit man can conceive, or numbers expreſs. How abſurd then and unphyſical were the notions and ſuppoſitions of the atomic philoſopers, who imagined to themſelves an infinite ſpace filled with atoms! For, though they ſhould ſuppoſe the bodies contained ever ſo large, and feign to themſelves an infinity of them to fill this boundleſs ſpace, the notion would ſtill be contradictory; becauſe the idea of filling neceſſarily brings to the mind the remoteſt or outſide body's being at the termination of infinite ſpace; which conception is deſtructive of any idea we can form of a boundleſs or infinite ſpace. It would be equally ridiculous to ſay in what point of infinite ſpace the univerſe was made, becauſe there is no conception of a ſite or local poſition in unbounded ſpace, all poſition and extent depending upon matter. All that we can ſay, therefore, is, that Omnipotence created matter; and as matter without bounds appears uſeleſs and inconſiſtent, that he has framed in material nature, and thus aſſigned the dimenſions of bounded ſpace by the creation, which alſo gave commencement to time or limitted duration. So as time is, as it were, an intercepted part of eternal duration: the material univerſe is alſo a limitted part of infinite ſpace, and may be conſidered as a ſphere of a determined magnitude, wherein all the bodies of nature are confined, we may ſay, as an egg within its ſhell.

SECTION II.

Cold, the quality of a real and material ſubſtance, proved from reaſon and experience.

ARCHELAUS, an athenian philoſopher, who lived 600 years before the birth of Chriſt, held that heat and cold were the firſt principles of all things. In this he differed from his maſter Anaxagoras, whoſe firſt principles were matter and ſpirit; the former originally in confuſion, but ſeparated, diſtinguiſhed and diſpoſed in the preſent beautiful order by the ſpirit. This notion ſeems to have been borrowed from the moſaic account of the creation, which the diſciple alſo might have admitted, altho' the powerful operations of heat and cold on all bodies might have induced him to make them primary phyſical agents; and in this caſe his opinion would have been entirely unexceptionable, had he analyzed and exhibited the ſubſtances on which theſe qualities depend; otherwiſe his opinion is unphyſical, as introducing qualities without principles or ſuſtaining ſubſtances; whence they are ſtiled occult qualities.

Boerhaave diſſerts largely on the effects of the two qualities, heat and cold, and ſhews that they are very forcible on all material beings; he alſo departs ſo far from the notion of abſolute qualities, as to make heat the effect of a poſitive being called fire. But he reaſons not ſo philoſophically on cold, which he makes the effect of perfect reſt; which notion is as indefenſible as the conception of heat, which he himſelf rejects; for he will not admit heat to be a motion of the particles of matter, without a cauſe aſſigned to produce that motion. We ſhall therefore endeavour to correct this erroneous conception admitted by ſo many philoſophers and chymiſts, and ſhew from the production, agency and powerful effects of cold, that it is neither a negative nor ideal quality, but the function or exertion of a real and material cauſe.

In our ſecond lecture we have obſerved that expanſive vigour, whereby heat, not only enlarges the dimenſions of all bodies, but even, if intenſe, deranges and expands their parts, ſets them in motion, and is capable of diſſolving the hardeſt bodies. On the other hand; we learn from experience, that cold reſtores fuſed metals to their original firmneſs by contracting their dimenſions, and uniting their parts. Doctor Boerhaave, in treating of cold, which he takes to be the abſence of fire, aſſerts that by the action of cold all bodies are equally affected; that no body was ever diſcovered, tho' ever ſo firm and cloſely compacted, but might be farther condenſed by it; even diamonds themſelves, the hardeſt of bodies, not excepted. Then treating of artificial cold he ſays, it has long ago appeared by chymical operations, that ſalts, the very inſtant they are diſſolved in water, will excite a greater degree of cold than was in either of them before the mixture, of which ſal-ammoniac is the principle: for putting one of Fahrenheit's thermometers into twelve ounces of water, the ſpirits ſtood therein at 50 degrees; then throwing into the water four ounces of ſalt, reduced to powder, and mixing them briſkly together with a ſtick, the ſpirits fell to the degree 25; whence he remarks, that ſal-ammoniac mixed in a ſubtriplicate portion, will generate 28 degrees of cold in this thermometer. Hence we ſee by experiment, that certain ſpecies of matter are productive of cold.

Fahrenheit's diſcovery on this head is worthy attention. Having ſpirit of nitre, ſo ſtrong as to be near one and an half the ſpecific gravity of water, and pouring two ounces of this upon a little ſcraped ice, and putting the thermometer therein, whoſe ſpirits ſtood at 40, they preſently ſunk to 4 degrees below 0; and having contrived a thermometer with quick-ſilver, which according to the temparature of the air ſtood at 16 degrees above 0, and put it into a mixture of ſeven ounces of that nitre and ſome ice finely powdered, the mercury fell 30 degrees, *i. e.* to 14 below 0. Here we may again obſerve, not only that there are matters productive of cold, but that of this number is a ſpirit, whoſe ſtrength is characterized by its weight; whereas in ſpirits productive of heat, the ſtrength is meaſured by their levity.

Boerhaave remarks, that the greateſt natural cold has never been obſerved to ſink the Thermometer below 0; and then all animals and vegetables that are expoſed to it die immediately: that art, however, has encreaſed it 40 degrees more. But to 32 degrees above 0, which is the freezing point, 40 be added, the heat of the air will then be ſo great that we could not bear it without refreſhment; whence it follows, that the encreaſe of cold produced by chymical preparations, exceeds the tranſition from our winter's cold to the ſcorching heat of the torrid zone. This great chymiſt conſidering the powerful effects and reciprocal ſucceſſion of heat and cold, obſerves, that if bodies are dillated by one, they are condenſed by the other: and that the condenſations are always in proportion to the intenſity of cold, &c. from which conſiderations he infers, that in every ſolid body in the univerſe there is a conſtant periſtaltic or oſſcillatary motion in all the particles which enter into its compoſition; and for this reaſon, he ſays, it ſeems that the great author of nature has ordained, that viciſſitudes of things ſhould be permanent and unalterable, that the whole univerſe might thus remain in perpetual motion, not only in the large bodies, but through their moſt intimate particles, that thus the production, encreaſe, decreaſe, and diſſolution of every thing might be brought about by the ſame univerſal law. In confirmation of this we muſt obſerve, that altho' 32 degrees above 0 in Fahrenheit's thermometer is ſuch a cold as prevents vegetation, being the freezing point, yet this cold by art will encreaſe ſo as to ſink it 72 degrees lower. Again, heat is formed to raiſe mercury 600 degrees above 0. What numerous changes therefore muſt bodies undergo between theſe extreme degrees, or between that heat, which vitrifies ſtone or iron, and the greateſt degree of cold, or that which freezes quick-ſilver?

It has every where appeared throughout this work, and conſtant experience ſhews it, *viz.*

that heat opens all bodies and obliges them to exhibit and put forth their powers and qualities. We alſo diſcover that cold again binds up the ſame bodies, and that it reſtrains and confines their powers and qualities. Heat gives life, generation and growth to animal and vegetable productions. Cold, on the other hand, prevents their growth, checks their vigour, reſtrains and even ſuſpends all their lively operations. In ſhort, theſe two qualities ſeem to act with magiſterial ſway, and at the ſame time in direct oppoſition, as if the Creator had formed two imperial powers of oppoſite principles to carry on all the operations of nature, and ſtill to counteract each other's effects, ſo as to produce a perpetual viciſſitude and animation of nature. For both extremes, continually exerting their influence over material beings, ſeem to labour with contending efforts to eſtabliſh a general *equilibrium*, and produce a ſtagnation of all motion. But the author of nature hath wiſely ordained, that their dominion ſhould be partial to librate the balance of nature, and alſo ſucceſſive, ſo that their actions ſhould rather produce a mutual irritation, than a mutual ſuſpenſion. Thus all the operations and alternations of nature are effected, either by their ſucceſſive predominancy, or common temperature. This mechanical mode of action between heat and cold has hitherto remained unknown, but ſhall be fully exhibited in the courſe of this work.

Cold, one of thoſe great agents, is conſidered in modern phyſicks, as it was by Archelaus, and all philoſophers ſince his time, an occult quality without principle or ſuſtaining ſubſtance, as a mere privation of heat, which antient philoſophers, either thro' art or thro' ignorance, ſtiled a privative cauſe, ſuch an one, however, as was capable of counteracting a powerful poſitive cauſe. Upon a proper diſcuſſion of the modern doctrine, which copies the antient on this head, cold will even appear an eternally exiſtent principle, to conquer which, the Creator is obliged to bring light into exiſtence; a notion not only unphyſical, but favouring of heatheniſh obſcurity. Heat and cold give various motions to the different parts of the atmoſphere; they excite currents, winds, ſtorms and meteors, whereby heterogeneous parts are blended, depurated, qualified, and aſſimilated for the purpoſes of nature, for which it becomes unfit when theſe changes ceaſe and its motions ſtagnate. The ſame may be ſaid of the earth and waters, which evidently appear to be under a like dominion. A ſhort review of the particular effects of each quality, according as it predominates, will verify theſe remarks, and open a viſto to further diſcourſes.

We have already ſeen, that our elaſtic matter, which is the baſis of powers and qualities, the ſource of vigour in vegetables and animals, and which derives its predominant power of expanſion from the light in its conſtitution; we have ſeen, I ſay, that this ſubſtance is reduced and ſhackled down by moiſture; and now we ſhall find that it is repelled, compacted, and condenſed by cold. For the contraction, which cold produces in bodies, is an evident indication of its operating that effect on their elaſtic matter, which in them is the principle of expanſion. The numbneſs, which the noſe, fingers, toes and other extremities of a perſon long expoſed to cold, or travelling through ſnow, acquire; the mortification of ſuch parts, and their dropping off, not unuſual in cold climates, or on high mountains, where the cold is intenſe and the ſnow of long continuance, plainly ſhew, that the elaſtic matter, wherein the ſtrength and firmneſs of the animal body, and the life and vigour of its ſpirits conſiſt, muſt have retired from thoſe ſlender parts, and left them to mortify and fall away, deſtitute of ſenſation, life or firmneſs. For the quantity of elaſtic matter, which reſides in thoſe parts, is inſufficient to reſiſt the cold that ſurrounds them, and, being remote from the body, is unſuſtained by the fund of elaſtic matter therein contained; wherefore it is forced to retire to the central fund to form a reſiſtence. So ſmall detached parties that are ſet in advanced poſts, when a town is threatened with a ſiege, on the enemy's approach are forced to retreat into the garriſon, there with united force to make a general reſiſtence. This powerful attack and hoſtile invaſion of cold upon the elaſtic matter is ſtill further confirmed and illuſtrated by the following inſtance, if fairly interpreted.

In the time of a hard froſt, bottles of wine expoſed to this extreme cold will freeze at the ſurface, and for an inch or two deep on all ſides, or even nearer the centre, according to the intenſity of the cold. On breaking one of theſe bottles, and cutting through the ice, a cup or ſpoonful of wine will be found in the middle very delicious and high flavoured, and far more excellent than what the bottle at firſt contained; and the ſmaller the quantity thus remaining liquid, the more exquiſite will it be. On the other hand, if the ice be melted, the fluid it yields will be inſipid and ſcarcely better than water, either in ſpirit, colour or flavour; all which effects ſhew, that the elaſtic ſpecies of the original liquor retired on all ſides from the invading cold, and carried with it towards the centre all its powers and qualities, which are the more ſtrong and ſenſible, in proportion as their baſis the elaſtic matter is more condenſed. If this ice were diſſolved by a natural thaw, inſtead of an artificial heat, the departed qualities might in ſome degree return to their former reſidence; which ſhews, what a difference there is between the operations of art and nature; and that ſpontaneous effects are a more true and infallible ſource of natural knowledge than artificial experiments.

From this laſt inſtance it may be reaſonably conjectured, that at the deluge much of the elaſtic ſpecies at, and near the ſurface of the earth muſt have retired from the cold of the encompaſſing waters towards the centre. The natural coldneſs of the water, together with the long interruption of the ſun's genial heat, which nurtures and preſerves the vigour of the elaſtic matter, ſhould have repreſſed this ſubſtance violently from the ſurface; and the elaſtic matter thus compacted and concentrated, ſhould have kindled to fire in the bowels of the earth, which on the receſs of the flood got vent through the fiſſures of the earth, and probably was the cauſe of vulcanos. Theſe vulcanos, whoſe fires are ſtill nouriſhed by the ſulphurs, minerals and other combuſtibles, which the earth contains, may be uſeful in preventing earthquakes, but may be detrimental in another reſpect; becauſe, by carrying off the elaſtic matter, they prevent that equal diffuſion of it, that might again take place, whereby this ſubſtance returning to the ſurface of the earth, would reſtore to the poſtdilluvians the vigour and fertility of the antedilluvian world.

The ſame theory of the elaſtic matter's retiring from cold, may alſo be tried by the following teſt. Let two thermometers of the ſame quality and dimenſions be provided, and placed on a window, expoſed to the open air, the one reſting on the bottom of a glaſs cup containing water ſo high as to cover the bulb, and the other ſuſpended in the open air. If during the time of a freezing cold, the ſpirits of that in the air fall lower than thoſe of the immerſed thermometer, it will prove the cold of the air is greater than that of the water, the principle of that quality acting more freely upon the air, and not being counteracted or reſiſted in that element with fires ſo denſe as are contextured with water. But, according as the cold invades the water and congeals its ſurface, the ſpirits will condenſe and ſink, the elaſtic matter of the water having then retreated towards the bottom. At length, when the congelation reaches to the bottom of the water, the elaſtic matter ſtill forced to retire, and thus condenſed under the bulb, will excite the ſpirits forcibly, and cauſe a ſudden riſe, not by paſſing thro' the glaſs into the mercury, that ſeeming incompatible with the continuity of glaſs, but by exciting the elaſtic matter of the glaſs to the ſame degree of expanſion and heat, as was produced in the elaſtic matter of the water by the action and compreſſive force of cold; and theſe qualities are in the ſame manner communicated from the elaſtic matter of the glaſs to that of the mercury, which occaſions the riſe. But this is to be diligently watched, leſt it ſhould eſcape the obſerver's notice; for the ſpirits, thro' their volatile nature, may ſuddenly contract and fall.

To give another inſtance, and at the ſame time explain a common phænomenon, it is obſerved, that moiſt hay or vegetables of any kind, ſtacked up in large heaps and well preſſed together, will, after ſome time heat, then burn, and perhaps kindle into a flame; becauſe the elaſtic ſpecies, of which vegetables contain a large ſhare, is concentrated towards the middle of the heap by the cold of the ambient air, where, thro' its expanſive nature it effervesces and ſtruggles to be enlarged from its confined ſtate. Theſe expanſive exertions generate heat, which cauſes a motion and conflict of the ſpecies and animates its reverberations, until fire and flame be produced. In like manner the elaſtic matter of the earth and its productions, retiring from the humidity and cold of the ſurrounding flood, was confined and violently compacted, and ſtruggling to expand by its action begat fume, which ſoon improved to flame. Whence the origin of hot ſprings and vulcanos; and whence alſo the heat of mines and collieries, which increaſes in proportion to their depth. Theſe and ſimilar phœnomena are ſo frequent and ſtriking, that ſome philoſophers were induced to think the central part of the earth a fire or ſun.

We may take another proof from electricity. The bar or prime conductor of an electrifying machine is always more ſtrongly charged, and emits more copiouſly in froſty weather than in hot, moiſt, or any other kind of weather; becauſe, when the air is extremely cold, its electric, or elaſtic ſpecies flows copiouſly to the fricted glaſs, whoſe excited heat invites it from the preſſure of the cold: as it accumulates on this, it acts with repulſive vigour, and paſſes into any conductor that is within the reach of its emanations, and then to the earth or any other touching or contiguous body not already ſaturated, all theſe being leſs cold than the air. But if all the conductors and the electrifying glaſs be inſulated, the electric matter may be accumulated to a certain degree of compactneſs, proportionable to the greatneſs of the cold, but no farther; for when both powers are equal, *to wit*, the expanſion of the electric matter, and the preſſure of the cold, I ſay when, theſe are *in equilibrio*, the introduction of more electric matter will render the expanſive force ſuperiour to the preſſive, and cauſe emanations from the bar or pregnant bodies, and prevent a further encreaſe of electricity. Therefore, if moiſture doth not intervene, the force of electricity will be as the force of the cold: conſequently the greater the froſt the greater will be the impregnation, &c. But moiſture, or humidity in the atmoſphere, is a clog to its action, as is inſtanced from the loſs of force in gunpowder, whoſe expanſion is reduced or ſhackled down by water, and from many other phœnomena, as well in common experience, as in electricity.

Now from all theſe obſervations and ſtriking effects it appears, that cold, whatever be its cauſe or principle, is a moſt powerful quality, and the ſole agent or natural power, calculated for, and capable to oppoſe and counteract heat. That abſolute reſt, i. e. the want of action or exertion (which impliſes the want of power as well as the want of motion) ſhould be the natural cauſe of cold, is perfectly inconſiſtent: for how could this want of action and motion invade bodies pregnant with elaſtic or electric matter, and force that expanſive agent to retire from its ſtation, to accumulate and compact itſelf in a very ſmall denſe body, as we have ſeen in the bottle of frozen wine or pregnant bar, and alſo in the water where the thermometer is placed? Such power of action, ſuch force of impulſe, cannot be called reſt, or any thing tending to reſt.

Again, ſince heat is the moſt vehement quality hitherto diſcovered in nature, muſt not cold, which is capable and ſeems formed to counteract it, be equally powerful? The elaſtic matter we know when compacted and excited is the moſt active, vigorous and expanſive principle in nature, what then ſhall we ſay of the principle of cold, which repels, compacts and confines it? If heat be an exalted quality on one ſide, cold is equally powerful on the other extreme. Theſe two qualities are extremes and limits in nature, between which all the operations and elaborations of matter are excited and performed. We have then reaſon to conclude with Archelaus, that heat and cold, or rather the ſubſtances, which ſuſtain and exert theſe qualities, are firſt principles in material nature; for no rational ſyſtem of phyſics will admit of a quality without a ſuſtaining ſubſtance. As then a principle or material ſubſtance is the ſource and *baſis* of heat and light, ſo cold and darkneſs muſt alſo have a ſource and material *baſis*, but of an oppoſite nature; for properties are as their eſſences, and *vice verſa.*

It is the reigning opinion that cold is a privation of heat, as darkneſs is of light. This is a principle which ſeems to me adopted by all philoſophers, at leaſt I have met none who oppoſe it. Nevertheleſs this opinion of ſubſtanceleſs principles is inconſiſtent with the works of Omnipotence, is entirely unphyſical, and muſt have proceeded from vulgar undiſcerning prejudice, without an accurate idea or proper conſideration of thoſe old and unexceptionable axioms, to wit, *there is no effect without a cauſe*, and *effects muſt be as their cauſes*; for in conſequence of theſe axioms, as cold and darkneſs have real and poſitive effects, they ſhould neceſſarily be allowed to ariſe from, or to have real and poſitive cauſes; otherwiſe negative ones or uncreations are to be admitted as powerful agents in nature, a thing incompatible with philoſophy and religion; for philoſophy will not allow a *nonentity* to operate and produce real effects; and religion will not admit of power, operation, or material of nature, which was not produced by the Omnipotent Creator. Cold then, which curbs, condenſes, reſtrains, and thereby invigorates heat; and darkneſs, which envelops and abſorbs light, are not to be conſidered as the mere abſence of the qualities they overcome, no more than light and heat are to be regarded as the mere abſence or negation of darkneſs and cold, ſo that we are to conſider all theſe to be the offspring of real and material agents.

We know from the focus of a burning glaſs, that light is the ſource of heat and fire, and we have from many arguments concluded: that the ſun is the focus or collection of the light deſtined for our planets. This is pretty clearly expreſſed by Moſes. He is not indeed ſo explicit with regard to cold and darkneſs, (altho', by the way, he ſpeaks of the latter as a real ſubſtance. (Gen. I. ch. 2d. v.) But ſhall we therefore conclude, that theſe qualities are uncreated? No, tho' the Scriptures were ſilent concerning the powers of nature, we ſhould of neceſſity derive the exiſtence of every material being, principle, power and quality from a ſupreme, ſelf-exiſtent cauſe: otherwiſe, contrary to the principles of phyſics, we ſhould admit an effect without a cauſe.

To ſuppoſe a quality without a ſupporting ſubſtance, is a contradiction in idea; becauſe the inſtant a quality is mentioned, the mind turns on itſelf, and inquires what it is a quality of; which operation of the mind is either an innate principle of reaſon, or a judgment founded on common experience, either of which motives is an authority for the juſtneſs and propriety of the queſtion, and a proof of the axiom it ſuppoſes, to wit, that all qualities have their ſuſtaining ſubſtances. This queſtion can only be anſwered by an affirmative reply, for it is impoſſible to conceive, how ſomething, which muſt neceſſarily be ſupported by and depend upon ſomething, can ſubſiſt on and be ſupported by nothing. Cold therefore and darkneſs muſt be ſupported by ſome kind of ſubſtance or ſubſtances.

Nor is the difficulty eluded by ſaying they are privative qualities; for, if ſo, they muſt have ſome privative ſubſtances to ſupport them. For the cauſe and its powers being in immediate connection, muſt ever be alike circumſtanced as to their mode and exiſtence, that is, they muſt be poſitive together, or negative together, real or ideal together; ſo that one can never be real, while the other is imaginary: and, in ſhort, what idea are we to conceive of a privative ſubſtance? Is it that it waſtes, conſumes, reduces, or deſtroys another ſubſtance? Is it that it oppoſes and counteracts it in power and quality? All theſe effects require a power in real action or an efficient cauſe, which muſt ever be a poſitive being. In ſhort, every agent in nature capable of affecting bodies, cauſing ſenſations, and producing ſenſible material effects, muſt be material. Cold, then, and darkneſs, from a multiplicity of arguments, muſt have their material ſubſtances. Whatever theſe be, they have hitherto lain buried in the *arcana* of nature; for we find no ſubſtance aſſigned for ſuch qualities in any ſyſtem of phyſics which has hitherto appeared; perſuaded, however, of its neceſſity, we ſhall enter on an inveſtigation of that ſubſtance after we make ſome inquiry into the nature and cauſe of darkneſs.

SECTION III.

Darkneſs a real and poſitive Quality, a Property of the Firmament. Cold, alſo, a Property of the ſame great Element.

ALONG with many other inſtances of infinite wiſdom, which ſtudents in optics diſcover in the formation of the eye, they remark the neceſſity of the black matter or tinge of the coroides, and its convenient ſituation for abſorbing the redundant light that enters the eye, which, if not thus ſtifled, would mix with the viſual ſpecies, and confuſe its impreſſion, ſo as to render the image it depicts too imperfect and ill defined for diſtinct viſion. The tinge and its utility, in this inſtance, are one proof of the neceſſity of a black matter having the property of abſorbing and ſtifling light. And, certainly, this abſorbent of light muſt exiſt in earth, air, and water; in ſhort, in all bodies, the luminous excepted; for, how otherwiſe ſhould the light of ſeveral candles or fires burning in a room or any other confined ſpace, inſtantaneouſly vaniſh, when thoſe luminous bodies are extinguiſhed or removed? Yet the fact is ſuch, heat may continue, but no appearance of light will remain.

The reaſon of this has been long a myſtery; and hence, why light as well as heat is not encreaſed in a cloſe room by the conſtant burning of candles or fire, or why the former vaniſhes upon the extinction of fire, while heat will continue a conſiderable time, are queſtions with Sir Francis Bacon, and might have been ſuch to philoſophers of every age, not having hitherto been reſolved. We may add this obſervation: light we have proved to be a material fluid as real as air or water; now either of theſe fluids will encreaſe and accumulate in a confined ſpace, into which it flows; ſhould not therefore light alſo increaſe and accumulate in ſimilar circumſtances? Neverthelesſs, a room or any other confined ſpace, is as ſtrongly illuminated at the firſt inſtant a candle is introduced, as after it has been there for many hours, when its light ought to have greatly encreaſed, as heat or water would have done, were the ſupply of either continual.

This queſtion is only to be anſwered by the ſuppoſition of an abſorbing dark matter in the air, in the room, and in every body and ſpace in nature, the luminous ones excepted: which dark matter imbibes and invelopes the luminous matter as faſt as it flows. And it is this abſorption that produces ſhadow behind opaque bodies, which interrupt the luminous ſubſtance, that would otherwiſe keep up the light of that ſpace, and replace the light continually taken in by the abſorbing matter.

If there was not ſuch an abſorbing matter in the air, room, &c. to prevent the encreaſe of light, and therefore to preſerve its conſtant uniformity in every place, into which it flows, reading, writing, or doing any ſort of work by candle light in any confined ſpace would be painful and even pernicious to the eyes: for the light continually flowing from the candle, and therefore increaſing in the room, being reflected back from the walls and ceiling, would ſtrengthen ſo prodigiouſly on every ſide, as to leave no darkneſs or ſhadow in the room; but, on the contrary, produce a glare of light in every part, which would be as painful and ruinous to the eye, as the conſtant view of the ſun or of a candle flame.

Light, we know, is a material ſubſtance; for that proceeding from a candle, lamp or fire is only a transformation of tallow, oil, or fuel, which are evidently material. Now, to think that a *nothing*, which is the ſame as a privative quality, or an *uncreated power*, (which the atomic philoſophers and their followers ſuppoſed darkneſs to be) ſhould inſtantaneouſly gorge a prodigious flood of luminous matter, is more like a dream than, that Pharao's poor cows ſhould ſwallow up the fat and well-favoured kine, and proves that philoſophers can dream as well as kings.

That there is a quality or colour without a ſupporting ſubſtance is ridiculous to imagine; but to ſuppoſe that an imaginary quality ſhould devour or conſume matter is the quinteſcence of abſurdity. On the contrary, that matter ſhould envelope, abſorb, or conſume matter, is as natural, as that matter ſhould beget or produce matter: and both are evident from the transformation of bodies, and conſonant to the works of nature. For generations conſtantly ariſe from corruptions, and the birth of one thing from the diſſolution of another, as we ſee in the ſeed and its produce, the tallow and its light, and other ſimilar transformations. Fire drinks up water, drought abſorbs moiſture; but it is not the qualities hot and dry, which abſorb the qualities wet and moiſt, but the body hot or dry abſorbs and envelopes the body which is wet or moiſt; for it is body, and not quality, that has dimenſions or capacity to incorporate. So alſo it is a black matter which abſorbs light, and not a ſimple colour; which, without a ſupporting ſubſtance, can have no capacity to envelope it. If, therefore, light does not encreaſe in a room, from the continual and ſucceſſive effuſions of candles or fires, and if the flood that fills it immediately vaniſhes, when they are extinguiſhed, a dark matter muſt exiſt in the room, by which it is abſorbed.

Again, when the atmoſphere is clear and free from clouds, we ſee a beautiful ſky: it appears by day a fine azure, and by night a ſhining jet. Philoſophers affirm, that this is not matter, but an appearance thereof ariſing from a want of power in the eye to ſee farther, or a ceſſation of viſion, where nothing is found to ſtrike the view; as if forſooth it was the eye that put forth its viſual rays to gain a ſenſation of body, ſo that in meeting no body, and ſtopping at the utmoſt length, to which the eyes can puſh them, they ſhould produce the ſame effect, and impart the ſame ſenſation, as if they were ſtopped by a body, and thus induce us to think there is really matter, where none exiſts. But the fact happens to be quite the reverſe; for the light comes from the object ſeen to impreſs its image on the retina of the eye, which like all our other organs is entirely paſſive, and muſt be acted upon to excite ſenſation. The eye only becomes ſenſible of an object, when the viſual ſpecies from that object to it depicts its image more or leſs diſtinctly on the retina; but, where there is no body to emit or reflect the luminous ſpecies towards the eye, there can be no light emitted or reflected, and conſequently no viſion: for viſion in that caſe would be an effect without a cauſe. Whence we may fairly conclude, that an appearance of body to the eye, or a due ſenſation of it from any other ſenſe, is a juſt indication of its exiſtence (the organ being ſuppoſed in its natural perfection, which is the caſe with the generality of men). We muſt alſo infer, that where no body exiſts before the eye, there cannot be a ſenſation of it. Indeed, a body may be before the eye without imparting a ſenſation, as the viſible ſpecies it emits or reflects, on account of its diſtance, may not reach the eye, in which caſe it cannot produce ſenſation, which is inſtanced in the teleſcopical ſtars. There may then or may not be a body where there is no appearace of it*; but there muſt be a body where there is an appearance of it to the eyes of all mankind. Conſequently the azure ſky we behold is a real body: firſt, becauſe it appears a body to all beholders: and ſecondly, becauſe it has a colour, and therefore a ſubſtance to ſupport and exhibit that colour. To explain the phænomenon otherwiſe, is in plain engliſh, to admit an effect ariſing from a defect of power, or to aſcribe the effect of a certain determined material cauſe to a mere nothing or negative cauſe. Let any one who is not biaſed by ſuch tenets, make uſe of his own eyes and of his own reaſon, let him look up of a bright day, when the clouds are ſeparated and detached from each other, and he will be as ſenſible of the firmament as he can be of a diſtant mountain, or of the clouds themſelves. It is conſpicuouſly ſeen far above the clouds, thro' the intervals between them, under which they float ſwiftly, if there be a briſk wind, while the firmament remains firm and unmoved.

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* *We neither ſpeak of the properties, ſize, or quality of the body, but ſimply of its exiſtence or non exiſtence.*

Is it not wonderful to think, that the heatheniſh principles of Democrates and Epicurius, tho' contrary to ſenſe, reaſon and experience, ſhould ſtill ſubſiſt? Is it not ſtill more ſurpriſing, that the light of ſcripture has never been employed to diſpel the darkneſs of theſe Atheiſtical principles? This unaccountable deficiency has in a great meaſure proceeded from the prevailing maxim, that a true philoſopher ſhould inveſtigate and argue from mathematics and experiment alone. But ſhould it not ſeem unbecoming in Chriſtian philoſophers, to reject, out of zeal for ſcientific rigour, the knowledge they might derive from the moſt authentic account of antient facts and the inſpired relation of the origin and formation of nature; and at the ſame time, without proof or experiment, to admit atoms and *vacuum* on the word of an Heathen? This inconſiſtency is the more culpable, as every one will allow, that a knowledge of the origin and production of any thing tends greatly to elucidate its nature and properties. But this inquiry muſt be defered, until we conclude our phyſical arguments on the materiality of darkneſs.

We have already explained the means, whereby the powers and qualities of one body are ſuperinduced upon another; and how water, which has ſo few ſenſible qualities, is impregnated with thoſe of other bodies. This we have ſeen is effected by a transfuſion of the matter or ſubſtance, which ſupports and is endowed with theſe qualities, which being incorporated with water, that fluid muſt of courſe be impregnated with the qualities, which the matter contained and carried into it: and again, other bodies may have new qualities ſuperinduced upon them by this liquor or impregnated water.

This transfuſion of ſubſtance is as conſpicuous in dying as in the making of decoctions.

Now many kinds of bodies are dyed black; conſequently, in this operation the matter endowed with that quality or colour is transfuſed into, and incorporated with the cloth or body ſo dyed. It is moreover obſervable, that theſe black bodies always abſorb light and reflect none, which is an experimental proof of the truth of this theory.

This is not a ſtrained or juggled experiment, like ſome often exhibited and miſconſtrued to ſupport an ideal hypotheſis; nor is it a ſolitary inſtance produced in favour of the theory. It is ſupported by daily experience; for blackneſs is every day ſuperinduced on a multiplicity of bodies, which exhibit its predominant power to a degree of evidence, which obtrudes itſelf on every philoſophick mind. For in treating of colours, if you aſk a philoſopher what is black? he will ſay a privation of light cauſed by a power in the black body to abſorb all the light that comes upon it. Conſequently philoſophers univerſally admit the abſorbing power in black bodies. However, they cannot pretend, that the black colour forms a vacuum in the body to cauſe this abſorption; becauſe dyers inſiſt that the weight of ſilk or any other cloth is encreaſed more by black than any other colour; which is an inſtance, that this abſorbing power is a property of a certain ſpecies of matter of a very ponderous nature.

But if we compare the two notions of certain philoſophers concerning black or darkneſs, we ſhall find, they blow hot and cold with the ſame breath to ſuit their convenience. For, explaining black in the heavens, they ſay it is a privation of light, which is loſt in infinite ſpace; but black in a body is a privation of light by an abſorbing power of the body. Thus a *plenum* and a *vacuum* have the ſame effect. Not to ſpeak of another abſurdity, to wit, that the ſame nothing ſhould be the ſtrong bulwork that fixes the ſtars, and by which the material world and its contending agents are all framed in.

It is then the inherence of a black matter in bodies that produces the abſorption of light, and that enables us to change the colour of bodies, by incorporating with one the black matter, which has been extracted from another. And the ſame principle is the cauſe of the abſorption of light in the heavenly ſpaces, by the diffuſion of this matter throughout all ſpace; a phænomenon, which can never be otherwiſe accounted for; the only cauſe of it, which has been hitherto aſſigned, being an uncreation or a *nothing*; for the black matter, its real cauſe has till now been undiſcovered, as was the ſubſtance of heat and light in antient times.

Atomick philoſophers, and perſons tinctured with ſuch principles, call darkneſs and cold *pre-exiſtent* or *uncreated* qualities; and even a ſcripturean might imagine, that Moſes implied ſuch notions in his account of the creation, when he ſaid in the ſecond verſe that *the earth was without form and void, and that darkneſs was on the face of the deep.* But he, who will conclude from this paſſage that darkneſs is uncreated, muſt alſo ſuppoſe the earth in its firſt rude and indigeſted ſtate to have been pre-exiſtent and uncreated, which might have been the origin of the doctrine of Chaos, and ſuch ſyſtems of the Heathen philoſophers. But ſuch a concluſion is entirely ill founded; for in the firſt verſe the inſpired author expreſsly declares, that *in the beginning God made the heavens and the earth, i. e.* gave exiſtence to the rude matter treated of in the ſecond verſe, and conſequently to the cold and darkneſs co-exiſtent with it, or rather to the matter endowed with thoſe qualities, to whoſe univerſal influence there was no check until heat and light, *i. e.* the ſupporting ſubſtance of light was brought into exiſtence, to temper and diſpel thoſe dreary qualities, to qualify, meliorate and vivify the groſs matter, and prepare it for the work the divine Architect had in contemplation.

The ſacred narrative then ſtands thus: the firſt verſe points out certain materials, which the Creator made for the work in deſign: *In the beginning the Lord created heaven and earth*, *i. e.* the matters of which the earth and heavens or firmament are compoſed. The ſecond gives a more particular deſcription of theſe materials, *to wit*, that *the earth was without form and void*, which is rendered thus, that the matter of the earth was inert and without quality, *i. e.* in the ſtate of inert matter, and blended with the matter of the heavens, to which blackneſs was inherent, and which cauſed the darkneſs that involved the whole maſs and depth of the creation; for depth or any idea of meaſure is unimputable to infinite ſpace. The third verſe points out the creation of new materials to warm, to illuminate, and to inſpirit thoſe already created, and to complete the ſtructure of the univerſe; *And the Lord ſaid let there be light, and there was light.* But in no part of this account do we ſee any thing employed, which was not firſt created and provided by Omnipotence. Whence then the notion of uncreated matter or pre-exiſtent qualities? It is reaſonable and conſonant to our idea of the Divinity to pronounce, that the divine Architect created and prepared all neceſſary materials previous to his works. Conſequently before he made the frame of heaven or earth he created the matters proper for them, as we are told in the firſt verſe, and endowed with the qualities deſcribed in the ſecond. Light, a ſpecies of matter diſtinct from theſe already created, gets exiſtence in the third verſe, and is blended with them for the purpoſe of forming and meliorating them for the works of nature, which are ſet in motion when the materials were all created. For the fourth verſe mentions their ſeperation, which at once implies their previous mixture, and ſhews, that light and darkneſs were real ſubſtances, for the operation performed on them, that is, their ſeparation neceſſarily ſuppoſes real material beings.

We have ſeen in our ſecond lecture, that inert matter is void of all qualities, except tangibility and extenſion. This has been inſtanced in white aſhes, which Boerhaave calls *pure maiden earth*, and inſiſted upon in all parts of this work. Moreover, we have ſhewn in our firſt lecture, that every ſubſtance and eſſence are coeval, therefore inert, *i. e.* the terreſtial matter had not then any ſenſible quality : conſequently the quality of darkneſs, which in *Geneſis* is mentioned as coexiſtent with the matters of the heavens and earth, muſt have belonged to the former, and enveloped the tereſtial matter, ſo as to authorize the deſcription given of the creation, before light was made. That the celeſtial matter or firmament, where the ſtars are ſet, ſhould be of a black nature, to abſorb the effuſions of thoſe luminaries, correſponds with the *fitneſs* of *things* and the wiſdom of the Creator.

For the firmament, or that part of primordial matter deſtined for the heavens and frame of nature, whoſe quality was darkneſs, and which conſtitutes the vaſt extended ſky we ſee, bounds on all ſides the great ſpherical vault, which contains the copernican ſyſtem : and this immenſe ſpherical vault the ſun is conſtantly filling with his effuſions of heat and light. Now conſidering that theſe conſtant effuſions from this fiery globe will be continually ſwelling the flood of light thence reſulting, how could any darkneſs or ſhadow be found within the bounds, to which his emanations extend, unleſs there exiſted in the ſame ſpace ſome abſorbing matter to envelope and ſtifle light, as faſt as it is effuſed by the ſun, which has its effect principally when an opaque body intervenes.

The followers of Democrates will ſay, that theſe effuſions of luminous matter are loſt in the vaſt *inane* or vacuum of infinite ſpace; wherefore, ſay they, in this ocean of light the part which lies next that *inane* not having a flow of this matter, by reflection or otherwiſe back to us, muſt be dark, as muſt alſo the ſpace in that line from the ſun; becauſe the body intercepts the ſolar beam, which ſhould illuminate it: and this dark ſpace behind the body is called a ſhadow or privation of light. But a room or cellar is not ſurrounded by ſuch an exhauſting vacuum; yet in either the ſide only of an opaque body next the candle is illuminated, while the reverſe ſides are dark and caſt a ſhadow behind them, notwithſtanding the ſtrength and firmneſs of the walls and their cloſe plaſtering or wainſcotting, which ſhould certainly confine light and prevent its flying off to infinite ſpace. Now on which of theſe two caſes ſhall we ground our data and form our judgment in order to infer of the other? The one is within our reach, and we are convinced of its reality from univerſal experience; the other is remote, and the explanation given of it is entirely problamatical. If we follow the rules of philoſophizing, we muſt ground our arguments in the known and proved caſe; and conclude, that the explanation of light's abſorption given in the other is as void of truth, as the vacuum it ſuggeſts is void of matter. Therefore we ſhall lay aſide prejudices, believe our ſenſes and pronounce, that the ſtarry canopy of the ſky is the *firmament* of Moſes, or great ſpherical mound, which incloſes the ſpace in which the planets move. This ſpace, as well as the room above mentioned, would be replete with an ocean of light, were it not terminated and occupied by a black ſubſtance, to abſorb and devour the effuſions of the ſun.

As we write for Chriſtians it is needleſs to vindicate the authority of ſcripture; but it may be objected that the language of the ſacred writings, which we adduce to corroborate our ſyſtem, is not always accurate or to be underſtood in a literal ſenſe, frequent mention being made of the riſing and ſetting of the ſun, and other expreſſions uſed, which ſeem to intimate that the earth is at reſt and the ſun in motion: it may therefore be ſaid, as ſcripture is not to be depended on in thoſe caſes, why ſhould we rely on it in other places relating to the ſtructure of the world, or the diſpoſition of ſuch part as are beyond the reach of ſenſe? To remove this difficulty, we need only conſider, that even in the preſent enlightened age, the moſt learned philoſopher or aſtronomer, if he is ſpeaking of the length of the days or nights, of a battle, ſiege or ſea-fight, will uſe the received expreſſions, *ſun-ſet*, *ſun-riſe*, the ſun's culminating or coming to the meridian, &c. without being expoſed to an imputation of ignorance; but, if he is to give a ſcientific lecture on aſtronomy or philoſophy, or an account of the ſtructure of the univerſe, he will then ſpeak with a critical exactneſs, and give an accurate deſcription, not according to ſenſe, but to the real order and diſpoſition of things. In the ſame manner Joſhua, David, and the other ſacred penmen uſe occaſionally the expreſſions alluded to, rather as current, than accurate; but where Moſes is inſpired to give a circumſtantial account, not of appearance, but of a reality unknown to men, and unatainable by ſenſe; there his expreſſions are calculated to convey, not a figurative, but a real meaning, and to give a juſt idea of what he deſcribes.

Moſes tells us, in his firſt chapter, that God made a *firmament of the heavens*, and ſet the ſtars therein: now ſuppoſe we did not ſee a fine jet-like ſky, in which, if we are to believe our eyes, the ſtars are fixed; ſuppoſe, I ſay, we had no ſuch ocular proof of what Moſes ſets forth, ſhould we not rather believe his inſpired words, recorded in a book whoſe authenticity we cannot doubt, than the aſſertions of an heathen philoſopher? Yet our chriſtian philoſophers will reject the inſpired declaration of Moſes, tho' ſupported by ocular evidence, and implicitly rely upon the heatheniſh principles of Democrates and Epicurus, tho' contrary to ſenſe and phyſical reaſoning. This defference for authority is due only to the declarations of the Divinity, and more adapted to the myſteries of faith than to points of natural ſcience. They, however, find no difficulty in adopting ſuch principles: they will tell you that the *firmament* of Moſes is nothing but the vaſt *inône* of Democrates and Epicurus, in which their atoms floated, and, according to them, jumbled out a world, which being effected, a vacuum remained between the bodies which compoſe it. And it is this vacuum, according to the followers of theſe ancient philoſophers, which puts on the appearance of a jet or blue ſky, altho' Moſes, in expreſs terms, calls it a *firmament*; an appellation not ſeeming to imply a vacuum, particularly as he mentions it, as a ſubſtance in which the ſtars are ſet. This declaration is confirmed by ſenſe, as we have before obſerved: and it is alſo the more conſonant to reaſon and experience; for it is more reaſonable to ſuppoſe bodies of any kind fixed in ſome material ſubſtance than fixed in *nothing*, which would then be the import of the text. Beſides, if the firmament of the heavens, in which the ſtars are fixed, were itſelf *nothing*, it would have been a falſehood, beſides an abſurdity, to ſay, and *God made the firmament of the heavens.* Relying, therefore, on our ſenſes, our reaſon, and the veracity of the inſpired penman, for the reality of the firmament, let us endeavour more fully to aſcertain its qualities.

As enlightened philoſophers have diſcovered that heat and light are two qualities of the ſame material ſubſtance; ſo we are now authorized to think, that cold and darkneſs are alſo qualities of one and the ſame ſubſtance, of a nature oppoſite to that of the ſun and ſtars. For as cold is a quality inimical and deſtructive of heat, a quality both poſitive and powerful, ſo certainly it muſt have ſome real poſitive ſubſtance to ſupport it. Having then ſhewn, that darkneſs and ſhadow are cauſed by the effuſions of the firmament, we ſhall now examine whether cold be not alſo an effect or property of the ſame celeſtial matter.

Cold is not generated in the earth; for if it were, the lower people deſcended into its bowels, the colder they ſhould find it; but experience evinces the contrary: for colliers and miners ſay, the deeper they dig their pits and ſink their ſhafts the warmer they find it; ſo that the more ſubterranean their ſituation the warmer, as if they approached nearer ſome hot body in the centre, as the matter has been explained by ſome philoſophers. We are informed that in Hungary there are ſalt-pits ſo deep and large, that families continue in them for ſucceſſive generations, the men working at the ſalt, and the women rearing their children and following their various domeſtic occupations. Here they find themſelves warmer, tho' ſurrounded with ſalt, than on the ſurface of the earth. Beſides, ſpring water in winter is found warmer than that of rivers. Caves in the ſame ſeaſon are warmer than rooms above ground. All which ſhews the earth to be rather a ſource or generant of heat than of cold, which is further confirmed by hot ſprings, volcanos and ſubterranean fires. Cold, therefore, has not its origin in the earth.

Water cannot be the origin of cold, being of a diffuſive nature, which proceeds from the great quantity of electric matter blended with it. This fiery matter emanates from it ſo copiouſly, as on dark nights to render objects viſible which could not be perceived on land; but it is ſtill more conſpicuous in the gleam of light, which iſſues from the waves daſhing againſt ſhips or rocks, or breaking againſt each other. Beſides, it is allowed that this quality of fluidity is owing to ſomething of an hot nature incorporated with the fluid body; which is confirmed from the congelation of water by intenſe cold. It is alſo remarkable that the congelation begins at the ſurface, and thence proceeds downwards, as if the cold came from abroad, which is again confirmed by the experiment of the two thermometers already mentioned. The continents and floating iſlands of ice that ſubſiſt at the poles and in other parts of the frigid zone, follow the ſame proceſs in their formation, and prove that cold comes from above; therefore its origin is not from the earth or water.

If we examine our atmoſphere, we ſhall find the lower regions thereof warmer than the upper. And thoſe who have made journies to the tops of very high mountains, ſuch as Ætna, the Alps or Crepacs in Europe, or the pike of Teneriff in the Atlantic, and the Andes in South America, affirm, that the higher they aſcend the colder the region; and that at the tops, which are above the clouds, the cold is extremely ſevere, perhaps not leſs intenſe than at the poles. Aerial travellers, who mount by balloons, ſay, the higher they aſcend the colder they find the region, except at the upper ſurface of a cloud which reflects light, there may be ſome abatement of this extreme cold. Cold, therefore, comes from above, and is not a quality of the air; for the air is compoſed of its baſis the elaſtic or electric matter, and the evaporations of earth and water therein buoyed up. We have ſeen that cold is not a property of theſe ſubſtances; nor can it belong to the electric matter to which it is inimical in power and propenſity, for cold exerts a convergent power quite oppoſite to expanſion, the eſſence of fire. Thunder, lightning, ſtreamers and fire-balls are ſo frequently engendered in the air, that the atmoſphere would rather be conſidered as a fountain of fire and flame than of frigidity, were it not found ſo intenſely cold in the higher regions. But from what we experience we have reaſon to conclude, that were theſe mountains higher than we have mentioned, the cold would be found ſtill more intenſe, and would continually encreaſe the nearer we approach the ſky. Conſequently the firmament, or ſome body therein contained, muſt be the ſource of cold. Now as it will be ſcarcely attributed to the ſun, ſtars, or planets, it muſt neceſſarily be a quality of the celeſtial matter or firmament itſelf, in which, according to Moſes, the ſtars are ſet.

That light and darkneſs are oppoſite qualities, like heat and cold, which are always moderating, counteracting, and undoing each other's effects, all people will allow. Where then could theſe magiſterial qualities be ſo commodiouſly placed as in the celeſtial bodies and frame of nature, to operate and bear ſway in their turns over all her bodies and powers? The expanſion and contraction of all bodies, the fluctuation of the air and other fluids, the variety and ſucceſſion of ſeaſons, the growth, perfection, and firmneſs of all productions depend on the powerful influence of heat and cold.

What then but the celeſtial matter and the bodies it contains ſhould be endowed with theſe imperial qualities to govern all nature, to excite ſubordinate powers to action, or reduce them to an equilibrium or a fluctuating ſtate? To prevent the extreme degrees of frigidity and torrifaction which would ariſe from the conſtant action of either of theſe two powers, the earth in her circuit round the ſun revolves about her axis and obverts each part ſucceſſively to the fountain of light and heat, and to the ſource of cold and darkneſs, with ſuch celerity, as to prevent the baneful continuance of either dominion, and to cauſe wholeſome and ſucceſſive changes with alternate incitements to action for enlivening nature and for effecting all her purpoſes. The ſeparate influence either of the luminaries or of the firmament, by which they are incloſed, being of ſuch prodigious force and efficacy as is neceſſary to animate nature, would be deſtructive to vegetables and other productions of the earth, or of any other planet, were one ſide too long expoſed to either power. To prevent then ſuch fatal effects from theſe irreſiſtable powers, the earth and all other bodies deſtined for like productions revolve about their axis, whereby a fluctuating temperature is effected and the viciſſitudes of day and night produced; both equally neceſſary for the beings of the earth, and equally impoſſible without this rotary motion, or ſucceſſive and alternate preſentation to the agents of material nature.

For, as without cold every thing would be parched and conſumed, ſo without darkneſs, its ſiſter quality, all ſpace would be filled with an accumulated glow of light, ariſing from the ſucceſſive and perpetual effuſions of the ſun, if there was not alſo a black matter conſtantly emanating from the firmament to abſorb light and moderate heat, both which effuſions moſt commodiouſly flow in and blend together to form the ætherial medium and vehicle of the planetary motions throughout the vaſt ſpherical ſpace around the ſun. And as the firmament and the quantity of celeſtial matter far exceed that of the ſun and ſtars, ſo its effuſions muſt be greater and its qualities more predominant in this ætherial medium. Hence it is natural for cold and darkneſs to ſubſiſt and be preſent in every part of this ſpherical ſpace, until heat and light come in, or be excited to correct and diſpel them; which predominancy of theſe qualities induced philoſophers to conceive cold and darkneſs primeval, uncreated, and merely the want of heat and light. Hence the cauſe of immediate ſhadow and darkneſs the inſtant light is intercepted or withdrawn from any part of the ſpherical ſpace, by the abſorption of this black matter, as we have explained with regard to a room. Hence the changes of day and night, of heat and cold, in the different parts of the earth, according to their poſition or relation to the heat and light of the ſun, or the cold and darkneſs of the firmament. The power of the laſt muſt increaſe on every planet toward Aphelion, and of the firſt in Perihelion, ſo that the motions of the planets round their orbits occaſion a new variety in the effects of theſe magiſterial powers.

The followers of the atomic ſyſtem were uſed to boaſt, that they had broke down the boundaries of nature; which evidently ſhews it had been the ſettled opinion from the beginning of time until that ſyſtem was broached, that material nature was framed in or ſurrounded by the firmament. Nor is this ſurpriſing, ſince the firſt philoſophers borrowed their knowledge, in a great meaſure, from the moſaic narrative. Theſe ancient innovators, however, contrary to the teſtimony of ſenſe, impoſe a vacuum on the world, as if a *nonentity* could exhibit the colour and firmneſs of a ſubſtance, fix the ſtars, and be the compacting frame of nature. They likewiſe, contrary to experience and all reaſoning, whether phyſical or metaphyſical, obtrude upon us qualities without a ſupporting ſubſtance; for cold and darkneſs are certainly qualities as well as heat and light. Notions like theſe are of the moſt pernicious tendency; for cold and darkneſs not being conſidered as ſubſtances, were not objects of creation, and might have paſſed for pre-exiſtent and eternal. This perſuaſion, being generally received, might have outlived the improvement of philoſophy, ſo that after a ſuſtaining ſubſtance was found neceſſary to ſupport theſe qualities, this newly-diſcovered ſubſtance, as well as the qualities themſelves, might ſtill be regarded as uncreated, which is ſubverſive of religion, and contrary to the honour of God, the ſole ſelf-exiſtant and eternal being, and alſo productive of other atheiſtical tenets,

LECTURE X.

The Cauſe of the Motion of Comets: the Direction of their Motion: their Compoſition, and the Nature of their Tails.

SECTION I.

Oppoſite Motions of the celeſtial Fluids, the Cauſe of the cometary Motions: this Theory illuſtrated from Experience.

THE whole ſpherical ſpace about the ſun is filled up with two fluids, the ſolar and celeſtial matters, flowing in oppoſition to each other, whereby their reſpective funds, the ſun and the firmament, are conſtantly interchanging and aſſimilating the effuſions of each other for their reciprocal ſuſtainment. Thus the original magnitude or quantity of each is continually preſerved; for neither can annihilate the ſubſtance of the other, but one gains what the other loſes; ſo that if one remains invariable in its magnitude, the other muſt alſo retain its original quantity. Now we find the ſun always of the ſame ſize and dimenſions; therefore the firmament continues of its original magnitude: and, conſequently, they preſerve their original quantities by a mutual traffic of ſubſtance, each receiving and aſſimilating as much from the other as it imparts thereto by its effuſions.

The compound fluid reſulting from theſe reciprocal effuſions, and filling the ſpherical ſpace round the ſun, is by no means uniform in all parts; it affords a great variety; but we ſhall only obſerve its difference in three remarkable parts. The two extreme parts contiguous to the funds are of the ſame nature with their reſpective ſources, from which they flow, and to which they are adjacent. The part, for inſtance, of this fluid immediately about the ſun, conſiſting of his ſubſtance yet unchanged, is of an hot, luminous, expanſive nature, diverging with centrifugal propenſity and unſpeakable force. The part of this fluid in the other extreme, or immediately flowing from the firmament, is of an oppoſite nature, frigid, black, and convergent, and preſſes from the concave ſurface, from which it iſſues towards the ſun with a ſtrong centripetal force. Thus the two extremes following their reſpective propenſities, blend their ſubſtance in the intermediate parts, ſo that a centripetal force is more prevalent, and the other qualities of the celeſtial matter more powerful where it predominates. But, on the other hand, a centrifugal force, together with heat and light, are predominant where the ſolar effuſions bear ſway.

Conſequently, there is ſomewhere in that ſpherical ſpace a middle region, not perhaps equidiſtant from both ſources, but at a diſtance from each, reciprocal to the quantity of matter it effuſes, partaking equally of their oppoſite qualities, and where the qualities of both are ſo equally blended and compounded, as to form a mean temperature between their native purity and rigidity. It might be imagined that the fluids in this middle region ſhould be totally at reſt, becauſe both meet with equal and contrary forces. This would certainly be the caſe, were theſe fluids compoſed of impenetrable particles, like a very fine ſand; but the oppoſing motions of ſuch atomic fluids would clog each other, and fruſtrate the deſtination of both; as, on the one hand, it would cloud the ſolar effuſions and obſtruct their progreſs to the regions he was deſtined to illuminate; and, on the other, would prevent the flow of celeſtial or alimental matter, neceſſary for his ſupport, from having acceſs to him. Therefore, to carry on this mutual intercourſe and traffic of ſubſtance neceſſary for the ſupport of both funds, each kind muſt proceed without much abatement of its motion according to its natural propenſity, until it arrives at the oppoſite fund, which can only be effected by a mutual penetration of theſe flowing ſubſtances.

This penetration of ſubſtances we ſee exemplified in light, which, though a material ſubſtance, pervades a variety of bodies, and muſt therefore enter into their dimenſions. The effluvia of gravity likewiſe pervades all bodies; for how otherwiſe can it effect a body more remote, while another intervenes, unleſs by paſſing thro' the firſt? But the penetration of the two fluids in queſtion is more clearly inſtanced in the following experiment: fill a bottle with brandy, or any other ſtrong ſpirit, then get a funnel or tundiſh, whoſe tube being put into, and tightly fitted to the neck of the bottle, that no liquor paſs between both, fill up the funnel with water. After the water has been poured in, it will not long continue pure, but will gradually acquire the flavour of the ſpirits; ſo that after ſome time the liquid at the top will be ſtrong by an acceſſion of the brandy and a deſertion of the water, which at length will entirely vaniſh by its deſcent to the bottom, from whence the ſpirits aſcend and remain in its place. Thus the ſolar effuſions aſcend to the regions of Aphelion, from whence the celeſtial matter, by a like pervaſion of fluid ſubſtances, flows to the ſun, its centre of propenſity, to reſtore the wanted *equilibrium*, which the ſun is conſtantly deſtroying by a conſumption of that ſubſtance. It is from a like cauſe, and for the ſame purpoſe alſo, that air preſſes into a fire; whoſe light, which is a diffuſion of its flame, paſſes thro' in the oppoſite direction; in which caſe, we know that theſe oppoſing fluids, viz. the air and the emanations of fire, inſtead of impeding, accelerate each other's motions, and are to each other a reciprocal ſpring and incitement to action.

and how much more ſo muſt it be with theſe elementary fluids, whoſe fountains are by ſuch traffic of ſubſtance the main ſprings of nature and of all her operations? No doubt the velocity of each fluid is greater before it comes to the middle region, according to its natural direction; but altho' the velocity of each then decreaſes, its *momentum* may ſtill increaſe on account of the accumulating quantity of its ſpecies which drives it on.

The ſun, the central body of our ſpherical ſpace, ſpreading his effuſions of heat and light to ſuch vaſt diſtances, muſt propel his luminous ſpecies in the direction of diverging rays, and by the power of his expanſion give it a prodigious centrifugal force on all ſides. Now let us conceive a certain quantity of this luminous matter, which the ſun may eject by one exertion of his expanſive vigour, and then ſuppoſe his faculty ſuſpended, until the quantity ſo ejected reach by its centrifugal propenſity the concave ſurface of the firmament. We ſhall conſider its vigour and denſity in three parts of that ſpherical ſpace, thro' which it is propagated in the form of a concentric flowing ſhell, conſtantly enlarging its dimenſions. Firſt we ſee this inſtantaneous effuſion has round the ſurface of the ſun the form of an hollow ſphere, in which this ſolar matter is of the higheſt vigour and intenſity. Its laſt ſtage is at the concave ſurface of the firmament, where again it forms a ſpherical ſhell concentric to the firſt, but whoſe radius is the ſame as that of our ſpherical ſpace. At this period, from its immenſe diffuſion, it muſt loſe all intenſity and force, ſo that its preſence there is not otherwiſe perceived than by the underſtanding; for its efficacy vaniſhes, and it eludes all ſenſation. Between both theſe extremes, let us alſo conſider it in the middle region, ſuppoſe equidiſtant from both. Its intenſity of ſubſtance here is a mean between the two intenſities at the extremes mentioned; for the intenſities are inverſely as the ſurfaces of the ſhells, the quantity of matter being the ſame in all, *i. e.* inverſely as the ſquares of their *radii*, *i. e.* inverſely as the ſquares of the diſtance from the ſun's centre. Therefore at the diſtance of twice the ſun's radius from his centre, the intenſity of ſubſtance and repulſive vigour of the luminous ſhell, is four times leſs than at the ſun's ſurface, and nine times leſs at the diſtance of triple his radius; ſo that at all parts of this vaſt expanſe, the powers and vigour peculiar to the ſolar effuſions ſhall be in the inverſe duplicate ratio of the diſtances of thoſe places from the ſun's centre.

In the courſe of our obſervations three properties of fire have occurred, differently appropriated to it, according to the uſes for which Providence deſigned it; for inſtance, the flame of a candle or lamp affords light copiouſly, without having any conſiderable heat or expanſion; culinary fires emit a ſtrong heat without much light or expanſive force; and thirdly, the flame of gunpowder poſſeſſes expanſion to a prodigious degree, and is no wiſe remarkable for the other two qualities mentioned. But doubtleſs the Creator has endowed the ſun with theſe three qualities in a degree proportioned to his magnitude and adequate to the purpoſe for which he was deſigned, *viz.* to invigorate our ſyſtem of planets, by diffuſing heat and light to, and even beyond the ſatellites of Saturn. Heat then and light he muſt poſſeſs beyond what we can conceive: but this would be uſeleſs for his deſtination, unleſs he were endowed with an expanſive vigour equally prodigious; for ſurely the force muſt be prodigious which is capable of propelling heat and light to ſuch immenſe diſtances with ſo much rapidity! Even at our diſtance from the ſun, in which thouſands of miles are as inconſiderable as feet and inches, how effectual is the power of a ſolar beam, not only on the eye, it's proper organ, but alſo on all other bodies which it excites to vegetation and expanſion, and above all in the focus of a mirror, where it pervades, diſſolves, and even vitrifies the hardeſt bodies! Nevertheleſs the force of this beam is not to the force of the ſun, as the ſhade of twilight to the intenſity of light in this focus, or as the ſize of this focus is to the magnitude of the ſun: conſequently the expanſive force of the ſun may be conſidered as infinitely to ſurpaſs that of gunpowder flame, and well requires that prodigious atmoſphere which Newton, notwithſtanding his ſtrong prejudices in favour of a vacuum, thought neceſſary to reſtrain and keep it down.

Let us now ſuppoſe a comet, or ſome ſuch body, laid cloſe by the ſun to receive an impulſe of his expanſive vigour, inſtantly, as a ball from a cannon it is projected in a right line towards the vaſt mound of celeſtial matter, which divides our ſpherical ſpace from that of the moſt adjacent ſtar in that direction. The motion of this body is accelerated as far as the ſolar effuſions prevail, *i. e.* as far as the temporate region; but on the other ſide, where the celeſtial effuſions oppoſe and predominate, the body begins to be retarded, and the more it advances towards the effuſive mound of celeſtial matter, the more the velocity it had before acquired is diminiſhed, until it be totally ſpent by the oppoſing motion of the celeſtial fluid. There its progreſs is ſtopped in aphelion, and the next impulſe of celeſtial matter forces it to change its direction, and again return towards the ſun in the ſame right line. In its return, the celeſtial matter gives to the body the ſame degrees of velocity, and in the ſame times and ſpaces as it had deſtroyed in the contrary progreſs. This is a property of all fluids whoſe operation is conſtant in a given direction, *to wit*, to generate in one direction ſuch motions as they deſtroy in the oppoſite one. Therefore the comet, arriving at the temperate region, will have recovered that velocity, which it had in quitting the ſame region, but in an oppoſite direction; and no ſooner has it paſſed this middle region, than the ſolar effuſions begin to oppoſe its progreſs, as forcibly as they promoted it before, and retard it in the ſame intervals, as they before accelerated it. So that the decrements of motion they now produce are equal to the increments they generated in the oppoſite direction, and affect the body equally in the ſame intervals of time, and at the ſame points of ſpace. Arriving then at the point where it was originally placed, it has remaining in it preciſely that force, which it acquired from the firſt impulſe of the expanſive lumen, but in a contrary direction; this force is inſtantly deſtroyed by a ſimilar impulſe: wherefore the body between theſe two equal and contrary actions is obliged to ſtop for a point of time in that point of ſpace, from whence it had been originally propelled. But again it receives a ſolar impulſe equal to the firſt, conſequently, it muſt again go off with the ſame velocity, and in the ſame line it had before purſued; and travelling thro' the ſame ſpaces and fluids as before, it muſt meet the ſame accelerations, and then the ſame retardations as before, and in the ſame ſpaces. It muſt therefore perform the ſame journey back and forward in the ſame time, while ever theſe cauſes continue to act. Thus the motion of a body is rendered perpetual in the ſame right line, as effectually as in any circular or eliptic orbit. This theory we ſhall now elucidate and confirm, not by any juggling contrivance, complex machinery, ſtrained experiment, or mathematic principles, but by ſimple and ordinary examples.

Let a piece of ordnance, a mortar, for in-inſtance, be erected perpendicular to the horizon and charged with a bomb and powder; the piece being fired, the bomb is projected in a vertical line, with a very great velocity, which it acquires from the expanſive force of gunpowder flame. This velocity, as the bomb aſcends, is continually retarded, until the entire motion of the body is deſtroyed by the conſtant and ſucceſſive action of gravity, which operates directly downwards. Conſequently, when the body ceaſes to aſcend, it muſt change its direction, and now acquire a new motion downwards in the ſame vertical line; and this new motion ſhall be accelerated in the ſame parts of ſpace, and in the ſame intervals of time, in which the former motion was retarded; ſo that the body ſhall gain the ſame degrees of velocity in its deſcent, as it loſt in its aſcent. For the operation of gravity is conſtant and gives the ſame impulſes in the ſame points of ſpace; whatever motion then it deſtroys any where in a given time in one direction, it will generate the ſame in the ſame time in a contrary direction. Wherefore the bomb returning in the ſame line, in which it was projected, falls into the mortar with the ſame velocity it had in parting from it: effects of the air's reſiſtence being excepted. Now if the mortar had been recharged during the abſence of the ball with powder, the ſame in quantity and quality with the firſt charge, and fired the inſtant after the bomb fell into it, would not the ball go off as before in the ſame vertical line (the mortar is ſuppoſed to retain its poſition)? would not the bomb perform the ſame journey up and down in the ſame time, and with the ſame volocity, while the ſame cauſes of motion continue to act with the ſame efficacy and in the ſame directions?

The aſcent and deſcent of a ſhuttlecock, when ſucceſſively ſtruck by a battledore with equal force, and always directed in the ſame vertical line, is an other inſtance to confirm our theory. For the phænomena in the preſent caſe will preciſely reſemble thoſe of the comet approaching to and receding from the ſun, except in this particular, that the tail of the ſhuttlecock in its aſcent turns towards the battledore, with which it has been ſtruck, whereas the tail of the comet is ever directed off from the ſun. There is alſo in both examples this diſparity, *to wit*, the force and velocity which the bomb acquires in falling is all deſtroyed together, by the ſhock or reſiſtence it meets from the mortar into which it falls; but the force and velocity the comet acquires in coming from Aphelion, is ſucceſſively and gradually deſtroyed by the repeated impulſes of the ſolar effuſions, which oppoſe its progreſs with increaſing force once it has paſſed the temperate region.

But altho' the mode of action be not fully exemplified, the efficacy of the cauſes aſſigned is clearly exhibited by phyſical agents perfectly analogous to thoſe aſſigned for the cometary motions. The expanſive and propelling force of gunpowder anſwers to a ſimilar power in the ſun: the mode of action alſo and powerful operation of gravity, in generating and deſtroying motion in oppoſite directions, exactly correſponds with the preſſive power of our celeſtial matter conſtantly flowing into the ſun for his nouriſhment. The cauſes, therefore, here aſſigned, have been evidently proved to exiſt, their operation has been illuſtrated by experiment, ſo that not to aſcribe the motion of comets to them, a perſon muſt reject real exiſting cauſes, which by all rules of analogy and reaſon, are capable and adequate to explain the cometary motions, and embrace in their ſtead the ideal agency of a ſubſtanceleſs virtue, while theſe real agents of nature are ſtripped of their efficacy, or left to buſtle about nothing.

SECTION II.

Cauſes of Deception in the Obſervation of Comets. Their Trajectories, rectilineal according to Kepler. Grounds for doubting the preſent Hypotheſis of eliptic Trajectories.

IT is clear from the foregoing ſection, that we ſuppoſe the Comets to move in rectilineal trajectories: but it is not to be imagined that we are driven upon this idea from the nature alone of our material agents; for it ſhall in the enſuing lectures appear, not only that theſe material cauſes are adequate for the deſcription of eliptic orbits, but alſo that they are capable of ſolving all the phænomena imputed to attraction. The preſent opinion with regard to the motion of comets is, that theſe bodies revolve about the ſun in very excentric orbits, according to the ſame laws, which regulate the planetary motions. But this opinion is ſubject to the moſt ſerious objections, from the cauſes of deception, from the phænomena of comets, from the judgment of Kepler, from the dubious grounds of that opinion, and finally from the very laws of that force, upon which that opinion of eliptic trajectories is principally grounded.

To proceed in order: firſt ſuppoſe a bird flying in a right line horizontally over the middle of a field in the plane of the meridian, and therefore parallel to the eaſtern and weſtern hedges or walls, at each of which a perſon ſtands to mark the bird's apparent path in the air. Let the ſpectator on the eaſt ſide obſerve its places, while it flies acroſs to the north, he will refer the bird ſucceſſively to the trees or objects on the weſt ſide from ſouth to north. Let then the ſpectator on the weſt note it's places during the return of the bird in the ſame right line from N. to S. he will refer it ſucceſſively to places on the eaſt ſide. If then both compared their obſervations, and made no allowance for the parallax that ſhould ariſe from their different ſituations, would they not conclude that the bird had deſcribed an elipſe round the field, having ſeen it fly along its oppoſite ſides, altho' in reality it flew forward and backward in the ſame line. To apply this, ſuppoſe the places of the comet of 1680 to have been obſerved by aſtronomers during the month of November while deſcending to the ſun, as was really the caſe. Let the ſame or others take its apparent places again during the months of December, January and February, when in receſs. During this interval the earth moved thro' a conſiderable arch of her orbit, not leſs than 98 degrees; which is the arch intercepted according to Newton between the nodes of that comet. Conſequently, tho' the comet had moved in the ſame right line, yet being viewed ſucceſſively on account of the earth's motion from different parts of ſpace, it ſhould have appeared to deſcribe two different lines in the heavens, each very different from its real path, and diverging from each other, according as the earth departs from that part of her orbit, in which the firſt obſervations were made. And, however deluſive this appearance, what a welcome phænomenon it is to a perſon, who takes it for granted, that no body can reſpect the ſun as the principle of its motion, without deſcribing an elipſe or parabola round him, which muſt be the opinion of all abettors of attraction by gravitation, as appears from the 1 Cor. prop. 13. l. 1. *principia.* And when phænomena are ſo favourable, analogy and calculation will remove other difficulties, for theſe two apparent paths, however ſtraight they be, may be brought to fall in with the ſides of an immenſely long parabola, and this again transformed into a very excentric elipſe. And tho' no comet has ever been ſeen paſſing from one of thoſe paths to the other, no more than the bird was ſeen paſſing from one ſide of the field to the other (this comet for inſtance was not ſeen from the twenty-fifth of November to the tenth of December, and was according to computation in perihelion on the eighth); yet the hypotheſis being founded on phœnomena, analogous to the planetary motions, and agreeable to the laws of gravity, with which a rectilineal motion could not be reconciled, aſtronomers will be eaſily induced to compleat the comet's orbit, and aſſign it an arch in Perihehelion and even in Aphelion, altho' never ſeen in either, and altho', in approach to the latter, the extending ſides of its apparent path are always diverging while ſubject to obſervation.

In the laſt inſtance we repreſented the bird as moving in a line parallel to the horizon. But if now we ſuppoſe it to fly, not horizontally, but in an oblique direction ſtill in the plane of the meridian, ſuppoſe from a great height on the ſouth ſide down towards the north point of the horizon; and inſtead of two ſpectators aſſume but one, who, while the bird is in motion from ſouth to north, is himſelf proceeding from weſt to eaſt; it is evident, that the former illuſions will be greatly encreaſed. For, while the ſpectator proceeds towards the eaſt, he will refer the bird towards the north and weſt; and thus inſtead of a right line, which it really deſcribed, he will imagine it deſcribed a ſemicircle, or ſome curve paſſing from the eaſt towards the north and then to the weſt; on which ſide it will apparently return, while the ſpectator is on the eaſt ſide of the field.

In like manner, altho' the comet of 1680 had deſcended towards the ſun in a right line nearly in the direction of the axis of the eclyptic, and had again aſcended from him in the ſame right line; yet it ſhould have been referred to places in the heavens eaſt and weſt of that right line, and ſhould have apparently gone over ſeveral ſigns, on account of the earth's having really moved thro' ſeveral ſigns during the viſibility of the comet: and the ſigns thro' which the comet apparently moved, might, or might not, be diametrically oppoſite to thoſe in which the earth was, according to the obliquity, velocity and correſpondence of the comet's real motion.

Another more ſimple inſtance for conceiving the errors to which the parallax ariſing from the earth's motion gives riſe, may be had thus: let a perſon hold up his finger before his noſe, and look at it ſucceſſively with each of his eyes, the other being ſhut; he will refer it ſucceſſively to parts of the oppoſite wall very diſtant from each other, at leaſt if the wall be ſomewhat remote. Now ſince the diſtance between the eyes is capable of producing ſo great a difference in the apparent ſituations of the finger; how great will not the difference be between the true and apparent places of the comet ariſing from the interval the earth paſſes over in one or two months? and how much greater in 4 or 5, eſpecially as the diſtance of the ſtars to which the comet is referred is ſo immenſely great? Yet, notwithſtanding theſe deceptions, which can only be obviated by continual and accurate obſervations, the paths of moſt comets have been inveſtigated from a few obſervations made only at their receſs. I have myſelf ſeen a comet about forty years ago, the phœnomena of which are ſtill ſtrikingly preſent to my mind. It ſeemed larger than a ſtar of the firſt magnitude, and its appearance was rendered at once beautiful and tremendous by a long and bright tail (ſee R. fig. 1, alſo fig. 2, pl. i.). It was to be ſeen in the weſt almoſt every night during part of October, all November, and part of December, for about ſix weeks. It then diſappeared, but appeared again in January following, and was to be ſeen every morning for about a fortnight or three weeks, after which it entirely diſappeared. This comet afforded an ample opportunity for obſervation longer and more conſpicuouſly in acceſs than receſs. Yet I find in the Philoſophia Britanica computations of a comet for the year 1743, (which appears to be the ſame I allude to) made according to the methods of Halley, Newton and Banquer, with a table exhibiting to the reader, as it is there expreſſed, *the wonderful agreement between the longitudes and latitudes of the comet by obſervation and computation.* Yet this table contains no obſervations during its acceſs, which muſt have been a great neglect or wilful omiſſion, and exhibits ſuch an exact agreement between the real and apparent places of the comet, as at once proves the method employed inadequate. For computation is applied to diſcover the real path of a celeſtial body and to rectify the errors of appearance, which, from what has been ſaid, muſt often amount to a number of degrees, whereas the apparent and real places, according to theſe tables, never differ more than a few ſeconds; and variations of latitude are alſo exhibited entirely inconſiſtent with the real path of a comet; but of this more hereafter, in ſpeaking of the comet of 1680; for we ſhall purſue in our remarks an order correſponding with the progreſs of cometary aſtronomy, which we ſhall collect from Dr. Halley's Synopſis. In the time of Ariſtotle comets were ſuppoſed to be ſublunary vapours or airy meteors; but Tycho, in the year 1577, obſerving a remarkable comet, and being provided with proper inſtruments, found it had no diurnal parallax, whence he proved it higher than the moon, which has a ſenſible one; he therefore placed its motion in the planetary regions. The ſagacious Kepler, who ſucceeded him, having the advantage of his labours and accurate obſervations, 'found the true phyſical 'ſyſtem of the world, and vaſtly improved the 'ſcience of aſtronomy; for he demonſtrated 'that all the planets performed their revolutions 'in elyptic orbits, whoſe planes paſs thro' the 'ſun, their common focus, round which they 'deſcribe areas proportionable to the times.— 'He alſo diſcovered that the diſtances of the 'planets from the ſun are in the ſeſquialtera 'ratio of their periodical times.—This great 'philoſopher had the opportunity of obſerving 'two comets, one of which was very remarkable; and from obſervations of theſe (which 'afforded ſufficient indications of an annual 'parallax) he concluded, that the comets mov-

'ed freely thro' the planetary orbs with a mo-'tion not much different from a rectilineal one, 'but of what kind he could not preciſely 'determine.' This is an intereſting period in the aſtronomy of comets, wherefore, before we proceed farther with this author, it is proper to make a few remarks on the obſervations of Kepler.

If authorities be of any weight in aſtronomy, (as undoubtedly they are with regard to phænomena which do not conſtantly occur) for whom ſhould we have ſo great a defference as for that prince of aſtronomers, who by the moſt accurate obſervations and the moſt ingenious calculations diſcovered the laws of gravitation, overthrew the circular hypotheſis of his predeceſſors, and determined the real figure of the planetary orbits? a diſcovery, which not only ſtands the teſt of all ſubſequent obſervations, but which we ſhall prove neceſſarily true, by ſhewing that the motions of the planets could not be phyſically perpetuated in a circular orbit, or in any other path except a right line or an oval orbit. Kepler had advantages for judging of and determining the path of a comet which few aſtronomers before or ſince his time could boaſt; and his opinion carries with it every appearance of unbiaſſed candour. For as to obſervations, beſides thoſe of his predeceſſor, he made many himſelf, having had an opportunity of obſerving two comets ſucceſſively: and certainly no man was better qualified to make them with accuracy and ſkill; for he had been long accuſtomed to obſerve the planets, to allow for parallaxes and optical irregularities, and even to invent methods whereby to diſtinguiſh their *real* from their *apparent* courſes; for it was by this accuracy and deep penetration that he was enabled to inveſtigate the true figure of the planetary orbits, and diſcover that univerſal harmony which reigns throughout all nature. No man could be more deſirous of finding the path of comets to be elyptic; for that would at once render his ſyſtem univerſal, and add to thoſe great diſcoveries which had already gained him ſo much renown. However, he candidly confeſſed, that comets were an exception to his ſyſtem, and repugnant to that law of gravitation of which he was the firſt inventor.

I ſay, repugnant; for altho' calculations and mathematical reaſoning, with the help of forces aſſumed in certain ratios, could make a body move round an elypſe, or deſcribe any other conic ſection; altho' the ſame extenſive ſcience could compute the times of eclypſes, oppoſitions and conjunctions in the Ptolemaic and other erroneous ſyſtems of aſtronomy, yet to explain the rectilinear motion of a comet by gravity, underſtood as an attraction, was beyond the power of geometry or calculation, while its return from the ſun is ſo ſudden and immediate. For ſince comets deſcend to the ſun nearly in a right line from a very diſtant Aphelion, they ſhould either fall into him, and ſo never return, or elſe paſs him by and go off to an Aphelion on the other ſide, being carried forward by the velocity already acquired; and this velocity being ſpent by the continual retardation it ſuffers in its receſs from the ſun on that ſide, the comet ſhould ſtop at length, and then return again in the ſame line, with a velocity continually accelerated as far as the ſun, and then capable of carrying it to its original Aphelion. Thus any comet moving in a right line and actuated by gravity, unleſs it ſtopped at the ſun, the centre of its attraction, ſhould paſs the ſun to a diſtance equal to that from whence it came. But in neither of theſe two caſes its return from the ſun could be ſo immediate as experience proves it to be, for in the former it ſhould be conſumed, at leaſt could never return from the ſun; and, in the latter, its return could only be after a ſeries of years, in which it would have paſſed to an Aphelion on the other ſide of him, as remote as that from which it originally came on this ſide. Therefore, the rectilinear motion which Kepler and Hevelius obſerved, was inconſiſtent with attraction. However, as their ſkilful computations and accurate obſervations convinced them the motions of comets were rectilineal, they never attempted ſhewing a relation between the trajectories of comets and the eliptic orbits of planets, of which Kepler himſelf was the inveſtigator.

But Sir Iſaac Newton, who excelled all others in that part of the mathematicks which relates to curves and conic ſections, and in applying mathematical reaſoning to the laws of motion and the operations of nature, ſeeing no means of reconciling a rectilineal motion with the principle of attraction, conceived the comets to deſcribe eliptic orbits, and extended to theſe bodies that law which Kepler had inveſtigated by obſervations, and which the diſcoverer himſelf, from obſervations more numerous and certainly equally ſkilfull, was obliged to confine to planets, aſcribing to comets a quite different motion. Let us purſue our order. 'At length, ſays Dr. 'Halley, came that prodigious comet of the 'year 1680, which deſcended (as it were from 'an infinite diſtance) perpendicularly towards 'the ſun, and aroſe from him again with as great 'a velocity. This comet (which was ſeen for 'four months continually) by the very remarkable and peculiar curvity of its orb above all 'others, gave the fitteſt occaſion for inveſtigating the theory of its motion. And the royal 'obſervatories at Paris and Greenwich having 'been for ſome time founded and committed 'to the care of moſt excellent aſtronomers, the 'apparent motions of this comet were moſt accurately, (perhaps as far as human ſkill could 'go,) obſerved by Caſſini and Flamſtead.'

'Not long after (continues our author) that great 'geometrician, the illuſtrious Newton, writing 'his mathematical principles of natural philoſophy, demonſtrated, not only that what 'Kepler had found out, did neceſſary obtain in 'the planetary ſyſtem, but alſo that all the phænomena of comets would naturally follow from 'the ſame principles, which he abundantly illuſ'trated by the example of the comet of the year '1680, ſhewing at the ſame time a method of 'delineating the orbits of the comets geometri'cally. This comet he proved to move about 'the ſun in a parabolic orb, and to deſcribe areas 'taken at the centre of the ſun proportional to 'the times. Wherefore, following the ſteps of 'ſo great a man, I have attempted to bring the 'ſame method to arithmetical calculations, and 'that with all the ſucceſs I could wiſh; for having 'collected all the obſervations of comets I could, 'I have framed a table, the reſult of a prodigious 'deal of calculation.' The table which Dr. Halley here refers to, relates to the motions of twenty-four comets in parabolic trajectories, which are all that have been duly obſerved from the year 1337 to 1698, aſſigning their aſcending nodes, with their perihelions, and the diſtances of their perihelions from the ſun, with reſpect to the diſtance of the earth, conſidered as 100000; after follow the conſtruction and uſe of this table, as may be ſeen at the concluſion of Whiſton's aſtronomy.

Here it is proper to obſerve, that the perihelion diſtances of moſt of the comets, as ſtated in the table, are greater than half the earth's mean diſtance from the ſun. Some therefore in perihelion were more diſtant from the ſun than Venus, and moſt of them more diſtant than Mercury; and ſhould therefore have afforded in perihelion ſenſible obſervations of the ſame phænomena, which theſe planets exhibit at their greateſt elongations, thoſe eſpecially whoſe trajectories made an angle greater than 30 or leſs than 120 degrees with the ſyzigia line when in perihelion. So that like thoſe planets, each of theſe comets ſhould have appeared direct, ſtationary, and retrograde in the perihelion part of their orbit, or between their ſuperiour and inferiour conjunctions, and all this ſhould neceſſarily happen in perihelion, did they go round the ſun between their acceſs and receſs. But Deſcartes, tho' he perſiſted in vortical motions, with many others, inſiſted that a comet was never ſeen in perihelion, *i. e.* on the contrary ſide of the ſun to that of it's aphelion; and indeed with juſtice, for the phænomena attending ſuch a ſituation would have been too ſtriking and amazing not to have been remarked. For were a comet ſtationary, its tail would appear moſt brilliant and extended full in our view for ſeveral nights ſucceſſively in the ſame part of the heavens, as if fixed to ſome ſtar, and would be one of the moſt magnificent appearances ever beheld. This ſupports Kepler's opinion, and forms another ſtrong objection to the hypotheſis of parabolic orbs, as does alſo the nature of ſuch orbits, which would never admit of perpetual motion, that curve not returning into itſelf. For as calculations grounded on the properties of the circle or elypſe do not agree with obſervation (however excentric the elypſe be ſuppoſed) ſuch orbits ſhould not be aſcribed to them, and conſequently no comet ſhould return to the ſun or have a periodic motion.

On the contrary, our hypotheſis (which we were compelled to embrace from the difficulties attending the preſent opinion, and which is ſupported by the numerous obſervations of one of the greateſt aſtronomers that ever lived) that hypotheſis, I ſay, is free from theſe difficulties, it explains the phænomenon of their perpetual motion without ever going round the ſun; and alſo ſhews, why they ſhould have an apparent parabolic path, while in reality they always move in the ſame right line: ſo that the difficulties againſt the preſent opinion are preſumptions in favour of that we propoſe. But without reſting on theſe circumſtances, we ſhall examine the grounds upon which Newton and his followers embrace this opinion, in order to diſcover how far it is ſupported by evidence or liable to exception.

Comets firſt occur in the fourth lemma of the third book of the *principia*, where they are proved higher than the moon, with many judicious remarks on their motions, in what caſes they are retrograde and ſtationary, and alſo on their accelerations and retardations, according as the earth moves in the ſame or oppoſite directions with them. In the illuſtration of the third cor. to this lemma, he firſt expreſſes his opinion as follows, ‘ I am out of my judgment if they ‘ (Comets) be not a ſort of planets revolving ‘ in orbits returning into themſelves with a per‘ petual motion.’ This opinion is erected into a concluſion in the fortieth propoſition, which is thus. *That the comets move in ſome of the conic ſections, having their foci in the centre of the ſun; and by radii drawn to the ſun, deſcribe areas proportional to the times.* Which he thus proves: ‘ This ‘ propoſition appears from cor. 1. prop. 13. l. 1. ‘ compared with prop. 8, 12 and 13. l. 3.’ The cor. cited in proof is this: ‘ From the three laſt ‘ propoſitions it follows, that if a body goes

‘ from a place with any velocity in the direction ‘ of a right line, and at the ſame time is urged ‘ by the action of a centripetal force, that is re‘ciprocally proportional to the ſquare of the ‘ diſtance of the place from the centre, the ‘ body will move in one of the conic ſections, ‘ having its focus in the centre of force; and the ‘ contrary.’ The application of this propoſition to comets depends on the univerſality of gravity, which is diſcovered to act in the above proportion on all planets, whether primary or ſecundary with regard to their reſpective centres of tendency. And indeed analogy authorizes a philoſopher to conclude, that comets being within the ſolar ſyſtem are ſubject to the ſame power, and therefore acted upon by a centripetal force in the inverſe duplicate ratio of the diſtance from the centre of force. Conſequently they ſhould neceſſarily move in one of the conic ſections, if the above propoſition, as it is expreſſed, be demonſtrably and univerſally true. But this is not the caſe; for if a body goes from any place in the direction of a right line *tending to the centre of force*, it will not deſcribe a conic ſection, but go in a right line immediately to that centre. Therefore the prepoſition is only true, where the right line of projection forms an angle with the direction of the centripetal force. Conſequently as it is in this place yet uncertain, whether comets were projected at an angle with, or in the direction of the centripetal force, it is not proved *a priori* that they deſcribe a conic ſection. It therefore remains to be proved *a poſteriori*, *i. e.* by their phænomena. This is not cavilling on words, but a real and important diſtinction to prevent a raſh deciſion upon the preſent queſtion, as if it was already proved by mathematics independent of the phænomena; and is the more neceſſary, as great men ſeem to have embraced the hypotheſis of parabolic trajectories rather from analogy and a mathematical ſpirit, than from a careful examination of cometary phænomena, from which alone the nature of their paths is to be collected with certainty.

Sir Iſaac prepares for the conſideration of phænomena by a few lemmas and propoſitions, purely mathematical, for determining intermediate places, longitudes, latitudes, &c. of a comet from certain ones given; and at length ſolves the great problem, which is the foundation of his theory of comets. This is not, from certain obſervations to determine what *kind* of path a comet deſcribes; but, *from three obſervations to determine the orbit of a comet moving in a parabola,* i. e. *ſuppoſing it to move in one.* And here it may be obſerved, that a parabola might be found by that cor. to paſs thro' any three given points in, or out of a right line. However, this theory he then applies to the phænomena of the comet of the year 1680, whoſe parabolic path he delineates from a table of obſervations made by Flamſtead, containing the comets places from the twelfth of December, 1680, to the fifth of February following. To which he adds another table of his own obſervations of the ſame comet from the twenty-fifth of February, 1681, to the ninth of March. He then gives a map of the ſtars in and near the left foot of Perſeus, accurately corrected, thro' which the comet paſſed during his obſervations. From all which he traces accurately the apparent path of the comet. Then follows another table of obſervations of this comet from the third of November, 1680, to the ninth of March, 1681, wherein the foregoing tables make the chief part. But in this are marked the latitudes and longitudes by obſervation and computation, with their reſpective differences for the times of obſervation.

Now, whether are theſe places by computation, and this delineated path, the real places and real path; or only the apparent places and apparent path, but rendered more accurate by computation? Whoever reads that treatiſe will find every where ſufficient ambiguity to give room for this queſtion. But we ſhall take it on both ſides. If theſe computed places and delineated path be but apparent, the real path and real places are yet undetermined, and may in this ſuppoſition be *rectilinear*; for we have ſeen that phænomena, like thoſe we treat of, might eaſily reſult from a rectilineal motion. So that after all the obſervations and calculations here made, aſtronomers have ſtill to diſcover what ſort of a path this comet really deſcribed.

But if this path, and theſe computed places, be real ones, they are ſubject to equal difficulties. For according to the laſt cited table, the differences between the comets places by obſervation and computation, or (as we now underſtand it) between the apparent and true places of this comet from the third of November to the ninth of March, are for the moſt part but of a few ſeconds, the greateſt difference being of 2′ 11″ in longitude. Now this agreement is inconſiſtent, as it would ſuppoſe that the comet did not vary its diſtance from the earth, nor the earth its ſite with reſpect to the comet during the whole time of obſervation more than would produce a few ſeconds or minutes difference. But what renders this inconſiſtency plain is this: The latitude on the twelfth of December was but 8° 28" and was continually encreaſing to the thirtieth of December, when it was 28° 11′. This aſcent of the comet from the ecliptic in eighteen days, ſhewed the elevated direction of its orbit, and agrees with the inclination of its orbit to the plane of the ecliptic. Conſequently, however appearance might vary on account of the increaſe of diſtance, this comet going off in the ſame direction, ſhould have continually increaſed its latitude to aphelion. But inſtead of the comet's thus aſcending towards the pole of the ecliptic, on the ninth of March, it's computed latitude is only 11° 45′, agreeing with the obſerved latitude, tho' both were the month before near twice as much. Now if theſe two computed latitudes be taken for the real latitudes of the comet, it is evident that at theſe two periods it did not move in the ſame plane, nor in the ſame orbit, unleſs we ſhall have recourſe to one of Ptolemy's largeſt epiſcycles.

Indeed, tho' the real latitude increaſed, we are not ſurpriſed that the apparent ſhould diminiſh; becauſe, according to the rules of perſpectives, the apparent altitude of any object higher than the eye will diminiſh, as its diſtance from the ſpectator increaſes. But that the latitude of the comet by computation, *i. e.* its perpendicular diſtance from the plane of the ecliptic ſhould decreaſe, while it is actually aſcending, according to the elevated direction of its orbit, is a proof that the computation is ſubject to, and partakes of all the occular deceptions. However, this deviation from the plane and orbit of the comet does not appear in the ſcheme delineated from theſe computations; for the places above mentioned are thoſe at M and N in the ſcheme, for which diſtance the orbit deviates very little from a right line, much leſs from the ſame plane. Upon the whole then we muſt conclude, that no real path of the comet was inveſtigated; or if that computed be called a real one, that it is entirely erroneous and inconſiſtent.

It is very remarkable, that the three places of this comet which were taken to determine the comet's orbit, were obſerved by Flamſtead on the 21ſt of December, when the comet was at N (fig. 2.) on the 5th of January, when at P, and the 25 of January Q; which three points are on the ſame ſide of the trajectory, and ſcarcely varying from a right line. From theſe alone, however, the parabola is conſtructed, which, without any difficulty, is transformed into an elypſe. And either no authentic obſervations were made on the comet's acceſs, or they are all omitted, except thoſe at I, K and L, i. e. on the 4th, 11th and 19th of November, which were made, not by Newton, Flamſtead or Halley, but by different perſons in different parts of the world; and which, notwithanding optical deceptions and defects both of ſkill and inſtruments, ſeem to have been ſelected as coinciding with the other ſide of the parabola inveſtigated. I ſay, ſelected, becauſe if Halley, Flamſtead, or ſome other famous aſtronomers, had not obſerved this comet in acceſs, and marked places more numerous and authentic than the three above mentioned, Doctor Halley would ſcarcely have ſaid, that *the apparent motions of this comet were moſt accurately* *obſerved perhaps as far as human ſkill could go*; nor would he have with authority aſſerted, that this comet deſcended almoſt perpendicular towards the ſun.

However, it is from the agreement between the places computed, according to the theory aſſumed and theſe obſerved places, that the theory of Newton and Halley was conſidered as confirmed and demonſtrated. But if, in like manner, the coincidence of the computed places of one or many planets with their places by obſervation were an abſolute confirmation of the theory aſſumed for ſuch computations, not only the hypotheſis of circular orbits, but the epicycles of Ptolemy, would ſtill continue uncorrected.; for the eclypſes, and conſequently the places of planets, with their oppoſitions and conjunctions, were calculated as well in that hypotheſis as in the preſent. Accurate calculations of ſuch phænomena were made and eclypſes foretold in the Ptolemaic and other ſyſtems. From all which known facts it follows, that accurate computations of the places or ſites of a planet or comet, are no decided proof that the theory aſſumed is true. This is particularly true of the comet, which did not afford repeated opportunities, like a planet, of bringing the theory to the teſt.

Had Kepler built his calculations on a few obſervations, and afterwards contented himſelf with making his computations agree with others, he ſhould probably never have corrected the circular hypotheſis of the divine Copernicus; or had Copernicus only attended to the diurnal and annual phænomena of the celeſtial motions, he would not have corrected the Ptolemaic ſyſtem. Had Kepler truſted to the obſervations of others, the theory of circular orbits would have been eaſily reconciled with them; but he was aware that few are ſo well verſed in optical irregularities, parallaxes, and other cauſes of apparent motion, as to authorize an aſtronomer to build a theory on their reports. But Sir Iſaac ſeems not to have been ſo cautious, either in the obſervations he adopts, or in the inferences he thence deduces. For thus he proceeds in the place already quoted: 'From all 'this it is plain, that theſe obſervations agree 'with the theory as far as they agree with one 'another, and by this agreement it is made clear, 'that it was one and the ſame comet that ap'peared all the time from November the 4th

‘ to March the 9th. The path of the comet did twice cut the ecliptic, *and therefore was not a right line.* It did cut the ecliptic, not in oppoſite parts of the heavens, but in the end of Virgo and beginning of Capricorn, *including an arc of about* 98°, and therefore the way of the comet did very much deviate from the path of a great circle. In the month of November it declined 3° from the ecliptic towards the ſouth, and in the month of December following it declined 29° from the ecliptic towards the north; the two parts of the orbit in which the comet deſcended towards the ſun, and again aſcended from the ſun, declining one from the other by an apparent angle of about 30°, as obſerved by Montinari. This comet travelled over nine ſigns, *to wit*, from the laſt degree of Leo to the beginning of Gemini, beſides the ſign Leo, thro' which it paſſed before it began to be ſeen; and there is no other theory by which a comet can go over ſo great a part of the heavens with a regular motion.. The motion of this comet was very unequable for about the 20th of November: it deſcribed about 5° a day, when its motion being retarded between November the 26th and December the 12th, *to wit*, in the ſpace of

'15½ days, it deſcribed 40 degrees. But the 'motion thereof being afterwards accelerated, 'it deſcribed near 5° a day till its motion be'gan to be again retarded. And the theory 'which juſtly correſponds with a motion ſo 'equable, and thro' ſo great a part of the hea'vens, which obſerves the ſame laws, with 'the theory of the planets, and which accu'rately agrees with accurate aſtronomical ob'ſervations, cannot be otherwiſe than true.'

Here a comet is ſaid to obſerve the ſame law as the planets, although its motion was ſenſibly ſlower between the 26th of November and 12th of December, when actually in Perihelion, than a little before or a little after; whereas experience proves, and the theory requires, that the planets move quickeſt in Perihelion. After this retardation, the comet was for ſome time accelerated in its motion, and ſoon after again retarded, which phænomena cannot be reconciled to its motion in a curve, or to the nature of attraction; but are entirely conformable to our theory, and may perhaps conduct us to a knowledge of the ſituation of the temperate region. For we have ſeen, that a comet approaching the ſun ſhould move quicker in this region, than from thence to Perihelion, where again its motion ſhould begin to be accelerated to that region; and then continually more and more retarded to Aphelion. The grounds upon which Newton eſtabliſhes his theory, as appears by the paſſage juſt quoted, are, that the path of the comet twice cut the ecliptic; whence he concludes, that it was not a right line; 2dly, from the agreement between computations made according to this theory, and the obſervations taken of the comet's motion, that his theory was the true law of its motion; and, 3dly, he draws the ſame inference from the impoſſibility of a body's going over ſo great a part of the heavens by any other theory.

But it might be objected to theſe reaſons, that altho' the comet had moved in a right line, its apparent path ſhould neceſſarily cut the ecliptic both in its deſcent and aſcent, in two points diſtant from each other by an arch ſomewhat like that which the earth had deſcribed during the interval of time between both interſections, viz. about 90°, as was really the caſe—that between the apparent and real motion of the comet the vaſt circle it ſeemed to deſcribe is eaſily accounted for — that the agreement between computation and obſervation is not ſufficient to eſtabliſh a theory; and in the preſent queſtion is rather an argument againſt the reality of the path computed. The truth of theſe remarks is clear from what hath been ſaid. It is unneceſſary to expatiate farther on theſe conſiderations, the ſyſtem we oppoſe being phyſically impoſſible as ſhall now be ſhewn.

SECTION III.

Inconſiſtency of the parabolic Hypotheſis. Comets tranſparent Bodies: and their Tails not Vapour but refracted Beams of Light.

'THE comet, (ſays Sir Iſaac Newton, 'Princ. 3d l. prop. 42.) which appeared in the 'year 1680, was in its Perihelion leſs diſtant 'from the ſun than by a ſixth part of the ſun's 'diameter.' And 'to this proximity (Doctor

'Halley tells us) the comet deſcended (as it 'were from an infinite diſtance) perpendiculary 'towards the ſun, and aroſe from him again 'with as great a velocity.' Theſe great aſtronomers have found the periodic time of this comet to be 575 years, and the tranſverſe or greater diameter of its eliptic orbit to be 138 times greater than the mean diſtance of the earth from the ſun, which diſtance, tho' immenſely great, bears no aſſignable proportion to the diſtance of the fixed ſtars.

It is found by experiment, that a body will fall thro' 16 feet in a ſecond of time, and alſo that it acquires ſuch a velocity, as, if continued uniform, would carry it thro' 32 feet in every ſecond of time after. But if it continues to fall by gravity, its velocity will ſo increaſe, that after the next ſecond it will have fallen thro' 64 feet; and at the end of the third ſecond it will have fallen thro' 144 feet; and thus will deſcribe ſpaces that are in the duplicate ratio of the times elapſed ſince the commencement of its motion. What velocity then ſhould a body acquire in falling thro' an height equal to 138 times the diſtance from the ſun to the earth, or in falling, by the ſame accelerating force of gravity, for between 2 and 3 hundred years? Nothing ſurely but the velocity attributed to light coming from the ſun can be compared with the velocity of this comet in Perihelion. Again, it is alſo found by experiment, that a body of a pound weight in falling from the ſame height of 16 feet into one ſcale, will acquire, from the velocity generated in its fall, a moment or force ſufficient to ballance about forty pounds weight in the oppoſite ſcale, What force then would a body of a pound weight acquire in falling thro' an height equal to the greateſt diameter of this comet's orbit; or in deſcending freely for two or three hundred years by its own gravity? Certainly the force of ſuch a body could not be imparted to it by any engine or piece of ordnance ever invented or conceived, with whatever charge or quantity of powder that could poſſibly be applied. Would it not, therefore, be a difficult matter to find a body of ſuch firmneſs and elaſticity as would be able to ſtop the comet moving with all this force and repel it, ſo as to make it move back immediately with the ſame velocity?

Let us now conſider the comet's path. According to the ſcheme, the two ſides of its parabola are almoſt parallel; and each of them is as rectilineal as any comet's path ever obſerved by Kepler. The comet likewiſe was more than a pound, or even ten thouſand tons weight, being probably as large as the moon, or not many times leſs than the globe of the earth. Its force therefore was inconceivably greater than that of the body before ſuppoſed. Nevertheleſs, this immeaſurable force and velocity, acquired by the comet in falling from Aphelion to Perihelion, is there ſo retarded, corrected, and bridled by the action of the ſun, and the reſiſtance of his atmoſphere, as to make the comet turn ſhort, and wheel round the ſun in a ſemicircle, whoſe radius is only $\frac{1}{3}$ greater than the ſun's radius. Nor is this all; for though powerful the ſun's attraction at this ſmall diſtance, and ſtrong the comet's tendency towards him, a mathematical property of conic ſections gives it ſuch an impulſe as to drive it perpendicularly from the ſun along the other ſide of the parabola. How conformable all this is to the doctrine of attraction!

To conceive more clearly the falſehood of this theory, let us ſuppoſe a diametrical perforation through the earth between us and our Antipodes three or four miles wide; into one end of this cavern ſuppoſe a denſe metalline body of a ton weight were let fall, would it not be very contrary to our preſent hypotheſis of gravitation, that this body ſhould bend its path within a few yards of the earth's centre, and with that ſhort radius deſcribe a ſemicircle round that point, and, inſtead of falling to our Antipodes, come up to us again along the other ſide of the cavern, with the ſame degrees of velocity with which it had deſcended, ſo as to deſcribe a parabolic path, whoſe focus ſhould be the earth's centre? The ſuppoſed path of this body directly correſponds with the parabola delineated for the comet, as the greateſt diſtance between the ſides of the comet's orbit is as ſmall in proportion to its length, as the breadth of the apperture ſuppoſed is to the ſemidiameter of the earth: and the diſtance of a few yards from the centre of the earth, is alſo proportional to the focal diſtance of the comet in the vertex of its orbit: there is, therefore, not the ſmalleſt diſparity; for the acting principle is likewiſe the ſame in both caſes and obſerves the ſame laws. All bodies near the earth tend or gravitate to its centre according to the ſame law and by the ſame principle, whereby comets, planets, and ſuch great bodies, tend to the ſun; conſequently, if we hold it impoſſible for a body thus to deſcend ſo near the centre, and there with a velocity ſo much accelerated turn ſhort, wheel round, and ſhoot up again, we muſt alſo, according to the Newtonian rules of philoſophizing, pronounce it impoſſible for the comet to wheel round ſo ſhort in Perihelion, where its velocity is ſo immenſely great. For a body in ſuch circumſtances to deſcribe a parabola anywiſe ſimilar to that repreſented in the ſcheme, is contrary to every law of nature and motion, notwithſtanding all the properties of conic ſections, and all the mathematic powers ever invented. A body let fall through a diametrical cavern in the earth ſhould, according to all writers on gravity, and all principles of accelerated motion, neceſſarily purſue its courſe to the oppoſite ſurface or Antipodes: and in the ſame manner a body falling along the path A. I. K. L. by the force of gravity, ſhould, by the immenſe velocity it acquires, be carried forward in the ſame rectilineal courſe to a diſtance equal to that from whence it fell. Even a well-trained horſe, or any other animal in full ſpeed, could not thus turn ſhort and wheel round without a conſiderable abatement of its velocity, and could not again recover the ſame ſwiftneſs in a contrary direction without a ſtrong exertion of muſcular force. Now we cannot attribute ſuch exertions to a comet. Shall the ſun then, whoſe ſole power, according to the reigning hypotheſis, is that of attraction, change, in a certain inſtant of time, the nature of his innate propenſity, and drive off the comet with a repulſive power, as a body is diſcharged from a cannon by the force of gunpowder. A power like this is preternatural or miraculous, and would argue not the invariable determination of a phyſical agent, but the elective faculty of an intelligent being. But, according to our modern philoſophy, every particle of matter, tho' inert, is admirably endowed with the *double faculty of attraction and repulſion*; the ſun, conſequently, having theſe faculties in proportion to his quantity of matter, ſhould exert both powers to a prodigious degree. But how he ſhould reſtrain the one and apply the other ſo ſeaſonably, is not eaſy to explain. However, on this foundation the parabolic trajectories in queſtion may be accounted for, if the ſimplicity of nature (which is the true foundation of every philoſophical rule and hypotheſis) will admit of oppoſite and warring powers in the moſt ſimple bodies, and if we had rather ſwallow the abſurdities of other men than make uſe of our reaſon. From the whole of what we have ſaid, it is clear that no comet ever doubled the ſun in Perihelion, or ever deſcribed a parabola, or any other curvilineal orbit; but that all move in a rectilineal path from Aphelion to Perihelion, without touching, paſſing, or doubling round the ſun; which at once agrees with the ſimplicity of nature, the principles of our phyſical theory, and the diſcoveries of Kepler, that moſt accurate and ſagacious aſtronomer. This theory of the cometary motions which we have propoſed, is both confirmed and exemplified in electric experiments; for a light body being ſuſpended near the charged conductor of an electrifying machine, will be continually flying to it and from it by the operative power of thoſe two principles, viz. by the preſſive power of the celeſtial matter which conſtitutes that part of air nutrimental to fire, and the expanſive power of the electric matter, as ſhall be explained in our lecture on electricity.

The application of electric principles to the motion of comets (which ſhall be explained in it's proper place) points out an utility in atmoſpheres which has hitherto been unobſerved. The atmoſphere of the earth, it is well known, is that body of air which envelopes it on all ſides to a conſiderable height. It is compoſed of thoſe various and heterogeneous matters, which exhale and evaporate from earth, water, &c. which extraneous matters, as the great Boyle has diſcovered, are all buoyed up and blended with a lively elaſtic medium, which is the real baſis of air. Now this extenſive fluid or atmoſphere, beſides many other advantages which may accrue from it, ſeems particularly deſtined for two great ends. It ſerves as a cloathing for the earth, or any other planet, to temper the extreme cold of the celeſtial matter, and alſo to moderate the exceſſive heat of the ſun in Perihelion. Thus all animals expoſed to the inclemency of the air are furniſhed with a covering of wool, hair, feathers, or down, which entangles the air, qualifies it, and forms round the animal a ſort of little atmoſphere, by which cold is moderated, and the animal heat preſerved. The ſecond advantage is almoſt peculiar to comets, which as they ſhoot in a right line directly towards the ſun, muſt have at the temperate region, a prodigious force and velocity. But here their progreſs is vigorouſly oppoſed by the ſun's repulſive emanations, which no doubt would have a moſt violent effect on either planet or comet in its approach, were it not for the interpoſition of their atmoſpheres. For this medium, beſides tempering the burning effuſions of the ſun, takes in, as does alſo the matter of the comet, much of the ſolar matter, which is thus conducted to it, and being ſtrongly impregnated therewith, becomes a repellent, whoſe expanſive emanations oppoſing thoſe of the ſun, a repulſive power is formed between both bodies when at a proper diſtance, and the comet, being the leſſer body, muſt without touching the ſun fly back towards Aphelion in the ſame right line, by which it came to Perihelion. This whole operation is ſeen in miniature in the motion of a light body to and from the impregnated bar, with this difference however, viz. that the light body approaches to contact before it is impregnated with repulſive matter; but the comet, both on account of it's expanſive atmoſphere, and the copiouſneſs and ſtrength of the ſolar effuſions, is ſufficiently impregnated to repel and fly off at ſome diſtance from the ſun.

Hence we ſee the reaſon why the atmoſphere of a comet ſhould be larger than that of a planet. For as planets revolve about the ſun in eliptic orbits, they approach the ſun obliquely in Perihelion, ſo that a ſmall repellent force will prevent their nearer acceſs and make them glide off to Aphelion. But comets, whoſe paths are in right lines to the centre of the ſun, muſt come towards their perihelion with prodigious rapidity, and therefore require a prodigious quantity of this repulſive matter to retard and at length ſtop their progreſs, which occaſions a receſs, and gives them motion in a contrary direction. This quantity of electric matter is ſupplied by the ſolar effuſions, and taken in by the vaſt atmoſphere with which the comet is ſurrounded; for during it's acceſs this atmoſphere is collecting and accumulating the ſolar matter prodigiouſly, until it is perfectly ſaturated, and then its expanſive vigour is moſt powerful, which acting againſt that of the ſolar emanations, a prodigious power of repulſion muſt enſue, and no leſs could retard or ſtop the progreſſive force of the comet to the ſun. But this cauſe taking effect in the vicinity of the ſun, not only the comet's motion is renduced and deſtroyed in that direction, but another equal to that is generated by the repulſive force in the oppoſite direction. Nor is it alone the quantity of the ſolar effuſions taken in which oppoſe the ſolar effuſions, but alſo the vaſt magnitude of the aſmoſphere thus replete, which preſents itſelf to the ſolar effuſions, and cauſes a vaſt retardation to the comet's motion towards Perihelion, eſpecially as it comes nearer to the ſun, where his emanations are more denſe. Thus the comets motion in that direction being continually leſſening until it is deſtroyed, it acquires a new one in the oppoſite direction. In its way back to Aphelion, it again effuſes its electrical matter which it had collected from the ſun, and which being exhauſted, its motion in that direction is reduced and at length overcome by the celeſtial matter; wherefore it is forced back again for another cargo of the ſolar matter, to diffuſe in its paſſage back again thro' the celeſtial ſpaces. Theſe cauſes of retardation and repulſion prevent the comet from falling in upon the ſun, where, far from being a nurturing fuel, it could only be a clog to his heat and vigour, like a ſlate, cinder, or any other ſpiritleſs body in our fires.

Theſe principles, whoſe operations we have explained, are capable of continuing the cometary motions in all poſſible directions from the centre of a ſphere to its ſurface; for on the one hand the ſolar effuſions pour from his ſurface on all ſides in a continuous flood, expanding and advancing towards the firmament: on the other hand, the celeſtial matter pours from the concave ſurface of the firmament on all ſides towards the ſun with convergent propenſity. A comet therefore in the direction of the plane of the ecliptic, of its axis, or in the poſition of any one of the ſun's diameters, *that is*, in any direction poſſible, may be driven along its rectilineal trajectory to and from the ſun, by the force of theſe two fluids, whoſe efficacy we know ſo well by experience in the powers of electricity and gravity, and which from their effects, operations, and univerſality, muſt alſo be the material agents, on which depend the conſtant motion of the planets in their orbits round the ſun, as ſhall hereafter appear.

We ſhall now return to the mathematical principles of Sir Iſaac Newton, and examine more of his opinions concerning comets. Speaking of the comet of the year 1680, 'Now (ſays 'he) if one reflects upon the orbit deſcribed, 'and duly conſiders the other appearances of

‘ this comet, he will be eaſily ſatisfied that the bodies of comets are ſolid, compact, fixed, and durable like the bodies of planets. For if they were nothing elſe but the vapours or exhalations of the earth, of the ſun or other planets, this comet in its paſſage by the neighbourhood of the ſun would have been immediately diſſipated; for the heat of the ſun is as the denſity of its rays, that is, reciprocally as the ſquare of the diſtance of the places from the ſun. Therefore, ſince on the eighth of December, when the comet was in Perihelion, the diſtance thereof from the centre of the ſun was to the diſtance of the earth from the ſame as about 6 to 1000, the ſun's heat on the comet was at that time to the heat of the ſummer's ſun with us as 28,000 to 1.’ ‘But the heat of boiling water is but 3 times greater than the heat which dry earth acquires from the ſummer ſun, as I have tried; and the heat of red hot iron (if my conjecture is right) is about 3 or 4 times greater than the heat of boiling water, therefore the heat which dry earth on the comet while in its perihelion might have conceived of the ſun, was about 2000 time greater than the heat of red hot iron.’

The ſun's heat on the comet was at that time, according to Sir Iſaac Newton, to the heat of the ſummers ſun with us as 28,000 to 1, &c. Doctor Boerhaave calculates that light in the focus of Villet's mirror was 7396 times more denſe, *i. e.* more hot than our common ſolar beam or ſummer's ſun. So that the intenſity of heat in the comet was near 4 times greater than that in the focus of Villet's mirror; or ſurpaſſed it more than that of boiling water does the ſummer ſun. But bricks, ſtones and flints, bones, metals, and all the hardeſt and moſt durable kinds of bodies were in a few moments calcined or vitrified in the focus of that mirror. Conſequently this comet, if of an earthy nature, tho' ever ſo hard or flinty, muſt have been turned into glaſs on the eighth of December, having been then more enveloped in the intenſity of the ſolar heat or that immenſe fire, than a ſcrap of flint could be in that focus when turned to glaſs. Rather we ſhould inſiſt that comets were all originally created of a vitrious nature; for the Creator has made nothing in vain, but every thing conformable to its end according to the *fitneſs of things*. Therefore, if comets were ſubject to the power of phyſical agents, like other bodies of the creaſion; they could not have been made of a tereſtrian nature, but of a vitrious matter, which is the moſt durable in the extreme degrees of heat and cold. It would have been vain to make them of earth, when in the firſt courſe they ſhould run, they would have been neceſſarily changed into glaſs; and their original nature entirely changed, which ſeems repugnant to the wiſdom and power of the creator. Beſides the rules of philoſophiſing will not permit us arbitrarily to ſuppoſe, that any thing has been created different from what it is diſcovered to be, and alſo what it's uſe in nature requires. Comets therefore always were, as now they appear to be of a vitrious nature, which we ſhall now prove by their other phænomena.

Comets have a moſt ſplendid appearance, and are, on account of their brilliancy, by all aſtronomers compared to ſtars. They are allowed to come from a very diſtant Aphelion, and to enter within the regions of Venus and Mercury; wherefore if they were opaque bodies, they ſhould exhibit all the variety of phaſes which Venus ſhews. Thoſe eſpecially whoſe Aphelion is in the northern regions towards the conſtellations, Draco, Cepheus, Lyra, Bootes, the Bears, or even nearer the plane of the eclipttck (from which northern regions moſt of them that have appeared ſeemed to have come) ſhould have put on various phaſes according to the aſpect in which they are ſeen between the regions of Mars and Mercury, during their acceſs and receſs; which phaſes ſhould be very conſpicuous when the tail appears at full length, at which time it would have a quadrate aſpect, then the comet if opaque, ſhould like Mars, Venus, or Mercury, be decotomiſed, gibbous or horned. Nevertheleſs, no comet has ever been obſerved to exhibit phaſes ſo defined in theſe poſitions. On the contrary, they are all conſtantly bright and ſeemingly luminous, ſome indeed appear more ruddy than others, but all are attended with a brilliant tail ſtretched in a line off from the ſun. This appearance induced many aſtronomers to inſiſt that the ſun's light paſſed thro' them as if thro' a lens or glaſs body. The comet which I ſaw when a boy, appeared to me (I very well remember) like a brilliant chryſtal, with a long fan-like tail, extended in a direction off from the ſun, which was then ſome hours under the horizon.

Since therefore aſtronomy is a ſcience which depends on obſervation; ſince it is the appearances of the celeſtial bodies alone, which can afford *data* for phyſical or mathematical reaſoning in that ſcience, what grounds has any philoſopher or aſtronomer to ſuppoſe that comets are opaque? If we conclude from the phaſes and ſhadows of ſome celeſtial bodies that they are opaque, becauſe ſuch are the conſequences of opacity upon earth: if again we conclude that other celeſtial bodies are luminous, becauſe, like luminous bodies upon earth, their luſtre is uniform on all ſides; what muſt we ſay of celeſtial bodies which have neither phaſes, ſhadow, nor uniform luſtre, but which exhibit a bright beam of light ſhooting thro' them on one ſide, in a line off from the ſun? We muſt undoubtedly conclude that they are tranſparent like a globe of chryſtal or glaſs which exhibit the ſame phænomena on earth.

Peter Apianus who ſaw the comet of 1530 and 1540, was the firſt who diſcovered that the tails of theſe bodies depend on the ſun? He was of opinion (and after him Cardanus, Tycho, Hevelius, and other aſtronomers who had alſo the opportunity of ſeeing comets) that the rays of the ſun are propagated thro' the the tranſparent head or body of the comet, and refracted, as through a glaſs lens, into a conical beam behind the comet, and always turned from the ſun. This opinion is rejected by Sir Iſaac Newton: but with what juſtice we ſhall now examine. This author ſays, in his treatiſe on comets, 'That thoſe 'who are of opinion that the comets tails are 'beams of the ſun's light tranſmitted thro' the 'comets heads, which they ſuppoſe tranſparent, are yet unacquainted with opticks, for 'the beams of the ſun are ſeen in a darkened 'room only in conſequence of the light that is 'reflected from them by the little particles of 'duſt and ſmoak which are always flying about 'in the air, and for that reaſon in air impregnated with thick ſmoak, theſe beams appear 'with greater brightneſs, and move the ſenſe 'vigorouſly; in a yet finer air, they appear 'more faint, and are leſs eaſily diſcerned; but 'in the heavens, where there is no matter to 'reflect the light, they can never be ſeen at 'all. Light is not ſeen as it is in the beam, 'but as it is thence reflected to our eyes, &c.'

Here this great author, inſtead of determining by celeſtial phænomena, whether a vacuum exiſted or no, once more ſets up that favourite ſuppoſition, and will admit no interpretation of the phænomena of comets however reaſonable, which will not ſquare therewith. Let us examine his reaſoning, according to him the viſibility of the ſun beam depends entirely on the particles of the duſt therein which reflect it. Certain it is, that the viſibility of opaque bodies depends upon light: but that the viſibility of light depends upon opaque bodies, is an inverſion of the order of cauſe and effect. I believe it has ever been the opinion of philoſophers before Newton, that light is ſenſible *per ſe*. And it is not wonderful that he embraced the contrary opinion, ſince his vacuum excluded that abſorbing matter from the heavens, on which ſhadow and darkneſs, as well there, as upon earth depends. On account of this abſorbent black matter, which is univerſally diffuſed, all parts of ſpace muſt be dark, except where the ſolar effuſions are ſucceſſively flowing; and the part of ſpace where they flow, muſt appear more luminous in proportion as they are denſe. A refracted beam therefore paſſing thro' a lens, or collected by a tranſparent body, ſhould appear conſpicuous in this dark medium. Now, comets being large tranſparent bodies, muſt collect and refract a great quantity of the ſolar light; which being compacted, muſt ſtrongly illuminate the ſpace it occupies. This collected light, being denſe when the comet is near the ſun, its tail ſhould then appear large and luminous, and grow ſmall and faint when the comet is more diſtant. It would be ridiculous to ſay, that light in the focus of a mirror is rendered viſible by duſt floating in it, when all bodies are conſumed in it; and if this compacted beam be viſible, *per ſe*, why ſhould not the beam, refracted by a tranſparent comet, which is alſo a lens, and has the power of condenſing light as well as a mirror. Light is alſo viſible in an exhauſted receiver.

Sir Iſaac Newton, notwithſtanding the denſity of fume and vapour which he requires in the comet's tails to render their light ſo ſenſible, in another place proves the rarity of their tails by the viſibility of the ſtars that are ſeen 'thro' them. This circumſtance is a ſtrong indication of the black matter of the heavens, and very unfavourable to the Newtonian ſuppoſition. For ſuppoſing this black medium, it muſt contraſt thoſe two ſpecies of light, and render them diſtinguiſhable from each other; the tail being but a thin beam of light thro' which the brilliancy of the ſtars appears. But if, on the contrary, the tail of a comet was made viſible only by the quantity of groſs vapour that ſubſiſted like clouds throughout its whole length, ſince the viſibility of the light depends on the denſity of the fume or vapour which reflects it, the tail to be ſo conſpicuous ſhould certainly be a very denſe vapour or very thick cloud. But ſuch vapour or cloud muſt neceſſarily obſcure the ſtars beyond them, in which caſe a ſtar of any kind could not be ſeen thro' the tail of a comet, for the ſtars are concealed from our view by the ſlighteſt cloud that intervenes. Since then ſuch a denſity of vapour in the comet's tail would intercept the light of the ſtars beyond it, and totally conceal them from our view, it follows, that their appearance through it overthrows that ſuppoſition, and proves that their tails are not groſs fume, but pure tranſmitted light.

However, we do not deny an atmoſphere about comets, having proved it ſo uſeful and even neceſſary for their motion. And if any one ſuppoſe foreign matter neceſſary for the viſibility of light, the atmoſphere we admit will anſwer that purpoſe. But then the queſtion ſtill remains, whether it be the ſolar light falling directly on the fumes of comets, or the beam tranſmitted thro' their tranſparent heads that form their reſplendent tails? Now, that the latter is the truth, is clear from all their phænomena. For the tail or beam of light which the comet reflects by refraction, ſhould be conical, and expanding from the ſun; as it is really obſerved to be. In the ſide view it ſhould appear like a fan, which is alſo the fact. In the after or front view, like a beard round the comet; and in the intermediate poſitions it ſhould aſſume appearances varying between both; all which agrees with obſervation. But that this conical beam ſhould appear like a broad flaming ſword, as if terminating bluntly in a point, as many people have ſeen, is the chief ground of objection to this theory. However, even this appearance is ſo eaſily accounted for, as ſtrongly to confirm our ſyſtem. For the comet being a ſpherical tranſparent body, (ſee plate I. fig. 2.) the light collected by it, as by a lens perfectly ſpherical, will be ſo refracted as to form a lucid cone, whoſe vertex is the focus of the ſphere, and will be at the diſtance of half the radius of the ſphere from its ſurface. This focal diſtance will be inſenſible on account of the remoteneſs of the comet from us; for on this account the apparent magnitude of a comet ſeldom exceeds that of a ſtar; but the meaſure of the angle under which a ſtar of the firſt magnitude is ſeen, eludes both art and ſenſe: conſequently the fourth part of that diameter, or the focal diſtance of a comet, ſhould likewiſe be undiſcernible; and, therefore, the vertex of the luminous cone ſhould appear to be at the comet's ſurface. Now, let ſections be made at *a. b. c.* &c. (pl. I. fig. 3.) in the conical body of light rectangular to its axis, and at different diſtances from its vertex: the intenſity of the light at each ſection, on account of the conſtant divergence, will be inverſely as the areas of the ſections, *i. e.* inverſely as the ſquares of their diſtance from the vertex; that is directly as the areas of the ſmall circles at thoſe ſections, which are inverſely as the areas of the ſections in which they lie. Again, the ſenſibility of light at different diſtances is as its intenſity, that is, inverſely as the ſection, or directly as the ſmaller circles within them, whoſe areas are made inverſely as the diſtance from the vertex of the lucid cone. Lines, therefore, drawn as tangents to theſe ſmaller internal circles, will determine and bound the ſenſible part of the comet's tail; for the parts without theſe tangents have not a ſufficient depth of attenuated light to render them ſenſible at ſo great a diſtance from the axis of the tail. Now as the circles are continually diminiſhing, and conſequently their tangents converging, the ſenſible tail of the comet, muſt likewiſe diminiſh, and at laſt terminate in a point. Hence it is clear, that the ſenſible tail of the comet ſhould have the appearance of a ſword or the flame of a candle, (fig. 2.) firſt enlarging, and then growing ſmall; for the part of the tail next the comet, being ſufficiently denſe in all parts to excite ſenſation, will be totally ſeen, and, therefore appear divergent, as it really is. But in a remoter ſection, the light being rare, there is no where a ſufficiency of it to affect the eye, except near the centre of that ſection: and in thoſe ſtill more remote, ſuppoſe the ſections *b.* or *c.* the light in the direction of the viſual diameter, altho' very rare, ſhall, on account of of its depth, ſtrike the eye; but the light in all other parts of that ſection ſhall vaniſh on account of its rarity. Conſequently the tangents Zy. and Xy. encloſe the part of the co-

mets tail, which alone has force enough to excite viſion; and as thoſe lines converge and meet in a point, ſo will the viſible tail of ſome comets after enlarging, grow ſmall, and aſſume a figure whoſe ſides being produced will end in a point.

The regularity of theſe appearances muſt be ſomewhat interrupted, as well from the atmoſphere which ſurrounds the comet, as from the clouds which float in ours; both of which occaſion great varieties in the comet's tail. For the light which its own atmoſphere collects, will make its head appear more full and lumpiſh, and will make its tail terminate more bluntly. On the other hand, the clouds of our atmoſphere, which are ſometimes rare, ſometimes extremely denſe, and generally in motion, will give the comet's tail an apparent tremor, and make it look like a ſtreamer or a flaming ſword. But when the atmoſphere is free from clouds, and the jet black firmament perfectly clear, if the comet be near Perihelion, where the intenſity of light is great, the tail will appear long and conical like a fan, altho' even here, from the reaſons above mentioned, it may alſo ſeem tapering towards the end.

Having now fully eſtabliſhed our own opinion, with reſpect to the tails of comets, we ſhall take that of Sir Iſaac Newton into further conſideration. This great author expoſes three opinions, which had prevailed among philoſophers with regard to the preſent ſubject; the third of which he embraces, *to wit*, that theſe tails are a kind of clouds or vapours riſing from the comet's head and tending to the parts oppoſite to the ſun. After a long courſe of reaſoning in ſupport of this opinion, he concludes thus: 'Therefore, the tail depends 'on the motion of the head, and not upon 'that region of the heavens in which the head 'is ſeen. They are not, therefore, made by a 'refraction of the heavens, but ariſe from the 'head, which affords reflecting matter; *for as 'in our air the ſmoke of a body ſet on fire aſcends 'upwards, and that, either perpendicularly if the 'body be at reſt, or obliquely if it be moved to one 'ſide; ſo in the heavens where bodies gravitate to 'the ſun, the fumes and vapours ought to aſcend 'from the ſun.*'

It is allowed, that when a body is ſet on fire, it produces a ſmoke, which aſcends perpendicularly or obliquely according to the ſtate of the body or the motion of the air. It is alſo well known, that this ſmoke is dark, denſe opaque, and void of light until it kindles into flame. When the ſmoke is elaborated into flame, by its heat and denſity the ſmoaky appearance will vaniſh, and the flame to which that vapour turns aſcends, and varies its poſition exactly like ſmoak; but will diffuſe light on all ſides as does a ſun-beam: for the light in both is expanſive, and will therefore be effuſed and propelled to all ſides. Therefore, ſuppoſing a vacuum, and that the origin of the lucid tail of a comet had been vapour, no reaſon can be aſſigned why it ſhould be more conſpicuous than a beam of ſolar light. For if this tail be a ſmoke or vapour, it cannot be luminous until it kindles into flame, and then the ſmoke vaniſhes, which is known by univerſal experience. (See our 4th Lecture.) Therefore, if it be ſeen without reflecting matter, ſo may the compacted beam; and if any reflecting matter be ſuppoſed to render it viſible, the ſame will ſuffice to reflect and render ſenſible the light of the collected beam or tail of the comet.

We ſhall now examine the tail as a vapour: let us ſuppoſe, for argument ſake, a vacuum in the heavens; Newton, where he treats of the refraction of light, in paſſing thro' mediums of different denſities, ſhews that the beam is bent towards the perpendicular in the denſer medium. The electric matter alſo is known to deſcend to the earth in *vacuo*, both which, as it is univerſally conceived, proceed from the ſuperior attraction of the denſer body or medium. If ſo, as like cauſes produce like effects, why ſhould not the comet's tail be turned towards the ſun, which, according to the Newtonian principles, exerts an attraction far more powerful than all the other bodies of our ſyſtem.

On the other hand, let the heavens be no longer a *vacuum*, and let theſe tails aſcend, not by attraction, but, as Sir Iſaac Newton affirms, as vapours and ſmoke do upon earth, viz. by the unequal denſity of the atmoſphere, which makes bodies of leſs ſpecific gravity than an equal volume of air aſcend to the more rare regions of the atmoſphere. If this be the caſe, whereas it is inſinuated in Newton's 21ſt quere, and with great juſtice univerſally believed, that the celeſtial ſpaces next the ſun are rarer than thoſe more remote, fumes, vapours, clouds, or whatever they'll have the comets tails compoſed of, ſhould recede from the more denſe parts, and tend to the more rare towards the ſun. Therefore again, according to this ſuppoſition, the tail ſhould be directed towards the ſun. Thus, in both caſes, according to analogy and to the principles and phyſical laws of Newton, if the comets tails were vapours, or produced by vapours, they ſhould be directed toward the ſun; which contradicts the conſtant phenomena; conſequently the ſuppoſition is wrong. And as the tail is always directed off from the ſun, it muſt be a collected light refracted by a tranſparent comet. Its direction is not changed by the motion of the fluids, which carry and impel the planets, even were this medium as denſe as water; for the rapid ſtream of a river will not bend or change the direction of a beam of light, nor will the wind, or even the ſtrongeſt blaſt of a bellows: and Newton, ſpeaking of the celeſtial fluid or ætherial medium, intimates that it is more rare than air itſelf.

Theſe things being duly conſidered, altho' the atmoſpheres of comets were ſo denſe and dark, that we could not perceive the tranſparency of theſe bodies, ſhould we not, from the poſition of the tail, the fan-like figure which ſome of them exhibit, from the viſibility of the ſtars thro' them, and, in ſhort, from all their phænomena, conclude that theſe tails are collected and refracted beams of the ſolar light, and, conſequently, the comets themſelves tranſparent bodies? This concluſion would be confirmed ſtill farther by a certain analogy in the bodies of nature; for inſtance, we have here upon earth, opaque, luminous, and tranſparent bodies; we already know of opaque and luminous bodies in the heavens; might we not therefore be induced to think that ſome of the celeſtial bodies are alſo tranſparent, even tho' we had not diſcovered them? And, doubtleſs, if we could ground any rational conjecture on the nature of the celeſtial bodies from their ſtate and mode of motion, we ſhould conclude, that the comets are of a kind different from the ſtars and planets. For we find the ſun and all other fixed bodies in the heavens, endowed with their own native light: we find, on the other hand, that all thoſe bodies which revolve in circular or eliptic orbits, like our earth, are, like her, dark and opaque: Now as the comets are neither at reſt, nor move in circular or eliptic orbits, it might be ſuppoſed they are neither opaque like the planets, nor luminous like the ſun, but of a different kind from both, *to wit*, tranſparent. Upon the whole, why ſhould not the heavens have their tranſparent bodies as well as the mines of Golconda? Was ever diamond or any diaphanous gem ſo conſpicuous an ornament in the works of nature, as the luminous head and refulgent tail of a comet filling a beholding world with ſurpriſe and admiration? Their appearance has ever been tremendous, and impreſſed mankind with terror and awe for the Supreme Being, who, in the comet and its flowing tail, ſeemed emblematically to hold forth a ſcourge over offending nations; whence, in ancient times, they were regarded as omens of the death of wicked kings or tyrants, and of the overthrow of ſtates; which preſages being commonly productive of repentance, amendment of manners, and a devotion towards the Supreme Being, rendered one comet of more utility to the earth, than, perhaps, all the ſtars and planets in the heavens. However, the tranſparency of comets does not depend on conjecture or analogy; it is as clear from the phænomena as the opakeneſs of the planets is from their phaſes. It is, therefore, needleſs to inſiſt farther on a matter as well demonſtrated as any point in aſtronomy.

LECTURE XI.

On the Planetary Motions and Attraction in general.

SECTION I.

The Planetary Motions mechanically ſolved, according to the Ratios geometrically inveſtigated.

NOTHING is more eaſily conceived than the aſcent and deſcent of a body in the ſame right line, accompanied with ſucceſſive accelerations and retardations, as it is familiarly, tho' not accurately exemplified in the aſcent and deſcent of a ſhuttlecock, or even of a ball toſſed upwards repeatedly upon the hand. The curve path, which a body deſcribes if thrown in any direction except a vertical one, is alſo obvious, and exhibited by daily experience in the continued ſtream of water iſſuing from a fire-engine, or from any other veſſel when the liquor it contains gets vent; or finally, by the courſe of a ſtone thrown from the hand. This curve, which is deſcribed by liquids or other bodies obliquely projected, is called a parabola, and is produced by the co-action of gravity, and of the projectile force acting ſimultaneouſly upon the moving body. For the body being acted upon together by both forces, and being obliged to yield to each in proportion to it's peculiar energy, muſt follow a kind of middle way between the directions of both forces, which in the preſent caſe generate a curve.

Hence we may clearly underſtand, that if a planet in Aphelion ſhould get an impulſe like a comet, not indeed in a direction towards the ſun, but in ſome direction oblique thereto, it would be forced to deſcribe a curve, being acted upon by two forces, *to wit*, that of the celeſtial matter, and that of impulſe or projection. The former would carry it directly to the ſun, but the latter impels it another way, and permits it to obey but partially and obliquely the influence of the former; the co-action therefore of both theſe forces would generate a parabola, but the diverging effuſions of the ſun expand, and round its path, into an ellipſe, which is a ſpecies of curve between the parabola and the circle. However, as the action of the celeſtial matter is conſtant and uninterrupted, the planet proceeds towards the ſun in its ſide-long direction until it comes into that part of ſpace, where the ſolar emanations prevail. Theſe emanations in this caſe act not in direct oppoſition to the planet, as they do with regard to a comet which moves directly to the ſun, and of courſe they do not retard its motion or oppoſe its progreſs ſo much as they would that of a comet, but rather bear it off from the ſun, gradually changing the direction of the planet from that of the centripetal force, which gives it the firſt tendency to the ſun; and ſince the ſpiſſitude of the ſolar effuſions is in the inverſe duplicate ratio of the diſtance from their ſource, their effects will grow more forcible according as the planet approaches nearer to the ſun. Beſides, they will be continually impregnating both it and its atmoſphere with electrical or ſolar matter, of whoſe repulſive vigour we have ſaid ſomething in the laſt lecture, but ſhall more fully explain it when we come to treat of electric and other attractions. We have therefore in perihelion a double cauſe for the diminution of that centripetal force which impels a comet or planet towards the ſun, and a real, permanent and mechanical agency to drive either from its perihelion back again to its aphelion, *to wit*, the electric ſaturation of the planet and its atmoſphere which generates repulſion in approach to the ſun, and alſo the increaſing ſpiſſitude of the ſolar emanations, which likewiſe counteract the centripetal tendency and prevents the nearer approach of the planet to the fountain of light, We need not therefore have recourſe to an adventitious, ſelf-generated, centrifugal force.

But it is to be remarked, that the centripetal propenſity of a planet is very different from that of a comet, the former coming obliquely towards the ſun in a curved path, while the other comes directly from Aphelion to Perihelion in a rectineal path. For this difference in their acceſs produces a correſponding difference in their receſs, for whilſt the comet, as hath been explained, is driven directly back from the ſun in the ſame right line by which it had approached, it like a light body to and from the electrified bar or prime conductor; the planet in the continuation of its curvilineal path diverges in-receſs gradually from Perihelion in an arch equicurved with that, in which it had approached it from its mean diſtance; and thence deſcribes in its courſe to the next mean diſtance, and thence again towards Aphelion an oval path ſimilar to that, which it had deſcribed in coming from Aphelion. For the ſources of the two forces which give the planet motion, and by whoſe action and compoſition it deſcribes one ſide of its orbit, retaining their former places, efficacy, and propenſities, muſt cauſe it to deſcribe on the other ſide to Aphelion a curve ſimilar and correſponding to that which their action before produced on this ſide, ſo that it will return to its original place in Aphelion; and there the ſame forces acting as before, ſhall make it return to Perihelion in its former path.

To illuſtrate the difference between the receſs of a planet and that of a comet, we muſt take notice that action and re-action are equal and contrary; and not that alone, but there is a correſpondence between the mode of action and that of re-action, *i. e.* if the one be ſlow or ſudden, the other ſhall be ſo likewiſe. This we have remarked and experimented in our lecture on the elaſticity of bodies, where it was found, that there is ſuch a relation between the reſtitutive act, and that of preſſure or impulſe, that both are alike ſlow, ſudden, or forcible. But to give an inſtance in point, it is well known that boiling water poured into a cold glaſs veſſel, will crack or burſt it. Yet chymiſts prepare glaſs ſo as to render it capable of bearing any heat, even to remain in very hot fire or flame without injury, and therein to boil any liquid, even mercury. This is effected by holding the veſſel full of mercury firſt at a proper diſtance from the fire until it is equally, warm thro' all it's parts, then by approaching it nearer, that it may acquire throughout all parts a greater degree of heat, and ſo on gradually until the veſſel coming to the verge of the flame acquires an heat almoſt ſufficient to make the mercury boil. In the ſame manner it is to enter the flame gradually until the liquor begins to ebulliate, when the glaſs is ſo tempered to ſtand the flame, that it may be left therein as long as you pleaſe. Now, as glaſs cracks and flies to pieces with a ſudden heat, which as ſuddenly excites the expanſion of its concrete fires, ſo a body being ſuddenly ſaturated with electrical matter, will as ſuddenly fly off from the excited electric, by which it is impregnated; and hence ſmall light bodies are fitteſt to exhibit ſuch phænomena of electricity. But when the expanſion of theſe internal fires of the glaſs is gradually enlivened by a ſlow and gradual heat, inſtead of acting with expanſive violence, it aroſe ſo ſlowly and gently as to expand or to enlarge the dimenſions of this extremely brittle ſubſtance, without occaſioning a crack or flaw.

In the ſame manner then a large ſuſpended body as one of our planets, when ſlowly and gradually impregnated with the electric or ſolar matter, is brought to ſuch a degree of temperature in its gradual and oblique approach to Perihelion, where it is perfectly ſaturated, as to effuſe a part of the expanſive fluid it imbibes: between which emanations and thoſe of the ſun, a repulſion is exerted prodigious indeed, and capable if it had been ſuddenly excited, of making the planet ſhoot off like a comet from the ſun; but having been raiſed by ſlow degrees, like the expanſion of the vitrious and mercurial fires, and its approach not being direct, but in a ſlant direction, it only begets an oblique gliding receſs, blended with the tenor of the planet's former propenſity. Between both theſe cauſes, the perihelion part of the planet's path ſwells into a circular arch, whoſe radius from this new divergent propenſity gradually acquired, will at length increaſe, ſo that after that the path will again deviate from a circle, and fall into an elliptic curve, ſimilar to that which it had deſcribed in approach to Perihelion. In this eliptic curve, the planet will proceed towards Aphelion, until overpowered by the increaſing centripetal force of the celeſtial matter, it is obliged to deflect from an elliptic into a parabolic courſe; which kind of curve it traces in Aphelion, and continues in, until the increaſing ſtrength of the ſolar emanations ſwells its paths once more into an ellipſe, and again, at Perihelion rounds it into a circular arch. So that the whole orbit of a planet is neither an ellipſe, a circle, nor a parabola at all parts, but an oval, *i. e.*, as it were, the ſection of an egg made thro' both ends in the continuation of its axis, which may be compoſed of thoſe three conic ſections, changing into each other.

To render all this more ſenſible (ſee plat. 2.): in this ſcheme the primitive circle paſſing thro' the ſolſticial and equinoctial points ♈, ♋, ♎, ♑ repreſent the ecliptic in the concave ſurface of the ſpherical ſpace, which the ſun at the centre S illuminates. From this central ſtation he pours forth his ſucceſſive effuſions, which fill that ſpherical ſpace flowing to all ſides *in orbem* from their ſolar ſource to the concave ſurface of the firmament, and cheriſhing with heat and light the ſyſtem of planets that revolve about him at different diſtances. Theſe ſucceſſive effuſions, (whoſe centrifugal force we ſaw in our laſt lecture is capable of repelling bodies from the ſun on all ſides, and of urging them to Aphelion in all directions), a rerepreſented by the ſeveral concentrick circles here deſcribed from the centre S. The intenſity therefore of this repulſive force at any of thoſe circles is in the inverſe duplicate ratio of its diſtance from the ſun; but the *conatus* of its power at each will be as the quantity of this matter encloſed in the ſpherical ſpace bounded by that circle.

Every ſphere is compoſed of cones, whoſe vertices form its centre, and whoſe baſes make its ſurface. Let then the trilineal ſpaces, formed by lines drawn from the ecliptic to it's centre, repreſent conical bodies of celeſtial matter, flowing convergently from all parts of the concave ſurface of the firmament towards the ſun, to nouriſh him and ſupply the loſs he ſuffers by his emanations; by theſe cones of matter bodies may be driven from Aphelion to Perihelion in all poſſible directions as were the comets. The centripetal matter, or ſolar aliment, which forms theſe cones, is indeed pure and uninterrupted in its action at the concave ſurface of the firmament its fountain, where the cauſe of the centrifugal force is entirely abſorpt; but the conatus of its power is directly as the magnitude of the conical body of this matter, which is behind every planet and preſſes it towards the ſun. The body at A, for inſtance, is preſſed in by the cone 1, whoſe vertex is at A. The cone 2, whoſe vertex is at B, is greater than the laſt, that whoſe baſe is at T, is greater again; and ſtill greater are the cones 5, 6, 7, &c. Thus the preſſure of this celeſtial matter on the planet is continually increaſing along with the magnitude of the cones, until the body arrives at Perihelion; ſuppoſe at R, which is at the vertex of the greateſt cone that acts upon any given planet.

Now, in the ſame ſcheme, ſuppoſe a body at A, projected in the direction AT, it will inſtantly be forced out of that right line by the tendency of the celeſtial fluid in which it moves towards the ſun at S; ſo that by the time the planet ſhould arrive at T in free ſpace, it ſhall, thro' the preſſion of this fluid, acting in the form of the cones 1, 2, 3, &c. be found at q, and therefore, inſtead of moving in the right line AT, it ſhall deſcribe the curve ABq. For the ſame reaſon, in its progreſs thro' the centripetal fluid it ſhall be driven in the continuation of the ſame curve to C, R, Q, O, &c. approaching as it proceeds ſtill nearer to the centre, and that with an accelerated motion on account of the increaſe of preſſure, which ſucceſſively occurs from the increaſing magnitude of the cones, which ſucceſſively act upon it in their tendency towards the ſun; ſo that if the body meet not with ſome force to counteract this tendency, it muſt, by the law of this kind of motion, proceed in a ſpiral path R, Q, O, &c. until it falls into the centre of its propenſity, which muſt be the planet's fate in a few revolutions, unleſs ſome other power ſupervene.

It would be vain to pretend that any increaſe of the planets circulating velocity will give it a centrifugal force ſufficient to overcome the centripulſive matter, and to bear it off from the ſun; for the velocity of a body thrown into the verge of a whirlpool, will increaſe, and even become prodigious, according as the body aproaches the centre of the vortex; nevertheleſs, this great velocity, inſtead of preventing, accelerates its abſorption. Even the exertions of animal ſtrength and agility (which cannot be attributed to a planet) tho' aided with the centrifugal force, which a rotary motion begets, are not capable of preventing the deſtruction of an animal engaged in one of thoſe fatal vortices. We admire the vigour and activity of a fiſh in water, particularly of a ſalmon, which will ſwim againſt the ſtrongeſt ſtream, and make the moſt aſtoniſhing leaps againſt the falling ſheets of a caſcade to get further from the ſea up rivers in order to ſhed and depoſit its ſeed in ſettled lakes of freſh water; the ſtrength of a whale is ſtill more ſurpriſing, nevertheleſs we have accounts of the piteable groans and forcible but uſeleſs exertions of thoſe creatures, when they happen to get within the vertical ſphere of the Malſtream off the coaſt of Norway, from which neither the rapidity with which they are carried round, nor their own exertions can deliver them; for they are ſoon ſwallowed up, daſhed againſt the rocks below, and at the return of the waters, ſeen to come up in ſhattered fragments by thoſe, who before were eye witneſſes to their affecting ſtruggles.

We are therefore, far from denying the neceſſity of a moſt powerful force to oppoſe the centripetal force, which is continually accelerating the planets tendency towards the ſun. Nor can we pretend to remove the difficulty by calling in either an imaginary ſpontaneous force, or a power purely mathematical, however elegant, ingenious, or happy this invention might appear, our ſyſtem is not ideal, but phyſical, and provided with a real centrifugal force ariſing from a material cauſe more powerful than that of gunpowder or electricity, but at the ſame time as analogous to both as the fountain of light can be to its ſlighteſt emanations. Nor could any power leſs great retard the motion and change the direction of thoſe vaſt bodies moving with accumulating force and velocity.

As the planet then proceeds from its mean diſtance, ſuppoſe at C, and approaches its perihelion at R, its ſpiral path widens into a more circular curve, round which it ſweeps ſtill with an accelerated motion; to which three forces at once concur in this its 2d quadrant of anomaly, *to wit*; 1ſt, the progreſſive propenſity of former accelerations, which continues in the body through it's quantity of matter; the 2d is a tendency towards the centre ariſing from the centripetal conatus of larger cones of celeſtial matter; the 3d is the centrifugal power of the ſolar effuſions, whoſe repulſive force increaſes with their ſpiſſitude, and now becomes a poiſe to the force of the centripetal cones. Mean time the planet and its atmoſphere accumulate impregnations of ſolar electricity, whoſe repulſive emanations increaſing with the accumulations, at length entirely deſtroy the ſpiral tendency of the planet near Perihelion. From thence therefore, by this and the 1ſt cauſe above noted, it proceeds thro' the 3d quadrant of anomaly in the continuation of the circular arch here deſcribed; but diverging into an elliptic curve towards the next mean diſtance towards ♎; like that from whence it converged from ♈ thro' the preceeding quadrant wherein it commenced that circular arch of its path thro' Perihelion. Thus it proceeds in the elliptic part of its path by X and U in receſs from the ſun, it's motion in receſs being ſuſtained by two powers, *to wit*, its progreſſive propenſity, which always continues in the body, and the diverging *conatus* it had acquired from the ſolar effuſions, which it retains thro' the laſt quadrant of anomaly. But its motion in this direction is now under the ſame cauſe of retardation that gave it acceleration in the firſt quadrant after it paſſed Aphelion. Here then its motion in receſs is entirely changed to that of acceſs by the ſole force of the celeſtial matter, for the electric effuſions and ſolar emanations are here entirely abſorbed, and the efficacy of the celeſtial matter (which ſways here) like that of every elementary fluid, prevails near its fountain, where the oppoſing powers are abſorpt. The planet then having paſſed its Aphelion, proceeds on as at firſt round its orbit, where it will ever continue to move while the ſun and firmament retain their places and propenſities with the mutual traffic of their effuſions.

Without drawing any parallel, or forming a compariſon between the agents here aſſigned for the planetary motions, and the ſubſtanceleſs cauſes now admitted by philoſophers, we ſhall give a further proof *a priori* of the exiſtence of our material principles, by ſhewing that they realize thoſe laws and conditions which mathematical reaſoning diſcovered to be the neceſſary qualifications of the forces acting on the planets. Thoſe who have read the *Principia*, cannot be unacquainted with thoſe ſtandard expreſſions of the centripetal force inveſtigated by Sir Iſaac Newton, prop. 6. L 1. which he calls ſolids. They may be applied to the ellipſe or to any other curve, whoſe naſcent or evaneſcent arch ſhall be of the ſame curvature with a circle at a given point. For by taking the value of the terms, which enter into the expreſſion, according to the properties of the curve aſſumed, we have in known terms the law and intenſity of the force, which in that kind of trajectory impells a body towards the centre. However it muſt be obſerved, that theſe expreſſions ſo ingeniouſly invented and accurately determined, are only the law or ratio of whatever power acts upon the planet, but not the power or force itſelf. Juſt as the numbers 20, 18, 12, &c. *pounds*, may determine the quantity of powder that will diſcharge a ball with a certain force; but if abſtracted from powder will not involve the efficacy of an expanſive force or affect matter being only ideal. We ſhall therefore, not only eſtabliſh the ratio of theſe centripetal forces or ſtandard ſolids, but alſo realize the material cauſe which acts according to them. If mathematicks and phyſicks ſhall be found to coincide, they will mutually ſuſtain each other. For thus Sir Iſaac Newton's inveſtigation, tho' deduced from idea, will be verified by fact; and that phyſical agent which is diſcovered to act according to the true and neceſſary ratio, muſt be conſidered as the real cauſe of that effect which accurately follows the ſame law and proportion.

The theorem we allude to ſtands thus: *In a ſpace void of reſiſtence, if a body revolves in any orbit about an immoveable centre, and in the leaſt time deſcribes an arc juſt then naſcent, and the verſed ſine of that arc is ſuppoſed to be drawn biſecting the chord, and produced paſſing thro' the centre of force; the centripetal force in the middle of the arc will be as the centripetal force directly, and as the ſquare of the time inverſely.* This is demonſtrated in the principia, but may be rendered more ſimple and brief thus: The force which makes a body deflect from its rectilinear direction in a given time muſt be as its effect in that time *i. e.* as the perpendicular diſtance the body diverges from the tangent line, which diſtance is expreſſed by the verſed ſine of the arch deſcribed. Again, the ſpaces deſcribed, *i. e.* thoſe verſed ſines thro' which bodies are urged by like forces, are as the ſquares of the times. Conſequently if the forces vary, the verſed ſines will be in the compound ratio of the forces, and of the ſquares of the times: therefore the forces muſt be as the verſed ſines directly and the ſquares of the times inverſely, that is, ſince vers ſin $= F \times T^2$.

$$F = \frac{\text{vers ſine}}{T^2}$$

(Cor. 1. ſee fig. 2. pl. 2. and thoſe at L & M, fig. 1). 'If a body revolving about the centre S, deſcribe a curve line, A P Q, which a right line Z P R touches in any point P, and from any other point Q of the curve Q R is drawn parallel to the diſtance S P, meeting the tangent in R; and Q T is drawn perpendicular to the diſtance S P. the centripetal force will be reciprocally as the ſolid $\frac{SP^2 \times QT^2}{QR}$ if the ſolid be taken at the magnitude which it ultimately acquires when the points P & Q coincide.'

For QR is equal to the verſed ſine of double the arch QP, whoſe middle is P: and double the triangle SQP or SP × QT is the exponent of the time in which that double arch is deſcribed. Conſequently the ſquare of that triangle, *i. e.* $SP^2 \times QT^2$ is as the ſquare of the time. But the centripetal force was as the verſed ſine QR directly, and inverſely as the ſquare of the time, that is directly as $\frac{QR}{SP^2 \times QT^2}$ therefore it is inverſely as the ſolid $\frac{SP^2 \times QT^2}{QR}$. ſo that in whatever form we take a triangle, one of whoſe ſides is the arch deſcribed by a body in a very ſmall time, and another, its diſtance from the centre of force, the ſquare of this triangle, divided by the verſed ſine will expreſs a ſolid, to which the centripetal force acting on the body is reciprocal in every point of its orbit.

Now, to realize the material force which acts according to this law or ſolid (which is the regular ſtandard of the centripetal force) to realize it, I ſay, in bodies compoſed of our celeſtial fluid, (for this can be the only real cauſe of the centripetal force) let us examine the figures L, & M in our orbit, which correſpond in every line and circumſtance with the fig. e. which was modelled on that conſtructed and referred to by Newton. We ſee this expreſſion, $\frac{S p^2 \times q t^2}{q r}$ which he calls a ſolid, is the area of a triangle ſquared, and divided by a line Q R. Every one knows a triangle is a magnitude of two dimenſions, and therefore its ſquare is a magnitude of four dimenſions, which being divided by a line is a magnitude of three dimenſions, properly a ſolid. It is not neceſſary to determine what particular kind of ſolid reſults from this, becauſe all ſimilar ſolids are in the triplicate ratio of any one of their dimenſions. But that which ſeems moſt natural and proper to aſſume is the cone generated by the revolution of the very triangle on which the ratio is founded, and chiefly depends. Let then the triangle S q p under conſideration be revolved about its ſide S p, and it will generate a cone. There are four cones ſo generated ſhaded in the figure namely, K, L, M & R, which repreſent the ſolids to which the centripetal force is reciprocal in thoſe parts of the orbit. Now, the little cones at their baſes 1, 3, 7 & 8, are the quantities of celeſtial matter which urge the planet from Aphelion towards the ſun; and their preſſure expreſſes the centripetal force at thoſe different parts, for they are the reciprocals of the great cones aforeſaid, which is thus proved.

The two parts into which a line is cut muſt be always either equal or reciprocal; becauſe the greater one part of it be, the leſs muſt be the other. If a line drawn from the concave ſurface of the firmament to the ſun, be therefore divided into two parts, theſe parts will be reciprocal; conſequently ſo will their duplicates or triplicates. Therefore, if theſe parts be the axes of ſimilar cones; theſe alſo are reciprocal, that is, the little cones, 1, 3, 7, 8, at the margin of our orbit are the reciprocals of the large ones K, L, M & R: therefore, according to Sir Iſaac Newton's theory, theſe little conical bodies of celeſtial matter flowing in to nouriſh the ſun are the true material powers which urge the planet at their vertices towards that central body, and not any ideal attraction, which if properly ſifted and rightly underſtood, has only expreſſed hitherto the effect produced by this preſſive fluid, as ſhall by and by appear. That all theſe cones are ſimilar, is evident to any one who conſiders the nature of the medium by which they are formed. For this black matter being impreſſed with one native propenſity to preſerve or recover the balance of nature, as we have remarked, and flowing from the ſame ſpherical ſurface with one univerſal tendency towards the ſame point, muſt have in all parts and at all diſtances from the ſun, the ſame degree of convergence. Conſequently, the vertical angles of the cones into which it can be reſolved are equal, and therefore all the cones are ſimilar, which proves the verification of the above expreſſion in our celeſtial matter.

Again, the oppoſing powers of thoſe parts of the ſolar and celeſtial matter which act upon any planet, continue in a certain ratio with reſpect to each other. For according to our theory, as the figure ſhews, where one is great, the other is ſo likewiſe; and where one is ſmall, ſo alſo is the other, according to their peculiar ratios. For inſtance, the planet when at the Aphelion A, is only acted upon by the ſmall cone 1 of celeſtial matter, and on the other hand is only re-acted on by ſolar effuſions which are there diffuſed and feeble. But at R the Perihelion it is preſſed in by the largeſt cone 8, and there the intenſity of the ſolar effuſions is alſo greateſt. And if a planet were ſuppoſed nearer to the ſun, both oppoſing forces would ſtill increaſe; but the electric repulſion, proceeding from the ſaturation of the planet and its atmoſphere with the ſolar emanations, would in every ſuch proximity render the centrifugal cauſe victorious, and drive off the planet to Aphelion. But what we are to obſerve is their proportions. The centripetal force of the celeſtial matter increaſes, it is evident, with the magnitude of the preſſive cone, which is in the triplicate ratio of its axis, that is in the inverſe triplicate ratio of the diſtance from the ſun. Again, the repulſive force of the ſolar effuſions is as their denſity, that is, in the inverſe duplicate ratio of the ſame diſtance. Therefore, in the compoſition of the two oppoſing forces, a ſimple centripetal force is predominant, which predominancy riſes to another ratio by the velocity of the celeſtial matter which increaſes in the inverſe ratio of the diſtance from the body by which it is conſumed, juſt as does the velocity of water approaching a caſcade, or that of air flowing to the fire which conſumes it. Whence upon the whole, the centripetal force is in the inverſe duplicate ratio of the diſtance from the ſun.

Thus the celeſtial matter, which we have diſcovered to be the true cauſe of the centripetal force acting on the planets, is found to obſerve that very law and proportion, which the moſt accurate mathematical inveſtigations, founded on the phænomena of nature, have deduced from geometrical *data*, without any knowledge of, or attention to the real and material cauſes producing theſe phænomena, and acting in that ratio. It will therefore no longer be objected to philoſophers, that a power purely ideal brings the planets towards the ſun, and that a mathematical idea or adventitious velocity is the only cauſe aſſigned for their receſs. It will not be objected that nature is complicated and inconſiſtent with herſelf as acting by her known fluids, air, light and water, on bodies here on earth by impulſe alone, while ſhe employs a contrary agency, *to wit*, that of a ſubſtanceleſs attraction in the heavens. It will not be ſaid that effects are pawned upon us for cauſes, and that the ſcience of phyſics is rather a mathematical inveſtigation of mechanical laws, than a reſearch after natural agents. In our ſyſtem, the maternal agent is diſtinguiſhed from its effects, and from the law it obſerves; the ſim-

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plicity of nature is preſerved and rendered univerſal; and in fine, real material cauſes aſſigned for the acceſs, receſs, and all the motions of the heavenly bodies.

SECTION II.

Attraction, duly underſtood, no phyſical Cauſe; but a name to diſtinguiſh one, not yet diſcovered.

IT is notorious, that many philoſophers at preſent treat of attraction as of a phyſical cauſe, which, according to them, gives an ultimate and ſatisfactory ſolution of all phænomena from the planetary motions down to the modifications of the moſt minute particles of matter in chymical experiments. And this principle is applied with the more confidence by aſſayers and minute experimentaliſts, becauſe it is a general perſuaſion, that the exiſtence of attraction hath been geometrically proved by Sir Iſaac Newton, and therefore with them ſhares the infalibility of mathematical demonſtration. But it has already been ſhewn, that it is not in the power of mathematics to inveſtigate the phyſical nature of any cauſe, the objects of that ſcience being ſolely magnitude and number. The agents of nature, the mode of action of theſe agents, their propenſities, &c. are to be diſcovered by inveſtigations ſtrictly phyſical, founded on an obſervation of the ſpontaneous obſervations of nature, and an analyzation of particular experiments; while the intenſity of forces, the proportions they act in, and the quantity or meaſure of the effects they will produce in given circumſtances are determined by the help of mathematic calculations applied to the phænomena. Now let any unbiaſſed perſon, qualified for the reſearch, take up Newton's principia, and examining them from beginning to end, ſee, whether he ſhall find one ſentence of a phyſical inveſtigation tending to diſcover the *phyſical nature*, *the ſubſtance* or *material agent* of the forces whoſe laws, proportions and effects are mathematically determined by that author. Let him examine, whether Newton does not always diſclaim thoſe inquiries, pronounce them foreign to his deſign, and declare himſelf totally undetermined about them, which would not be the caſe if he had determined them by mathematics, or were they capable of being anſwered by that ſcience. Finally, let him ſee, whether any ſkilful reader can collect more from theſe works with regard to attraction, than that ſecondary planets tend or gravitate to their reſpective primaries; that the primary planets gravitate to the ſun; and that all bodies tend or gravitate towards each other by *ſome force*, whoſe intenſity is as the quantities of matter, and inverſely as the ſquares of the diſtances (ſee the 7 firſt props. 3d b. Princ.); but whoſe *nature*, i. e. whether it be attraction or impulſion, and whoſe *cauſe*, i. e. whether it be matter or ſpirit, is totally unknown, undetermined, and not even inquired into. One clear and deciſive proof that this illuſtrious geometrician never conſidered the exiſtence of what is called attraction as mathematically proved, is, that at the concluſion of all his works, he propoſes a phyſical ſolution of the tendency of bodies towards each other by the impulſe of a fluid univerſally diffuſed, called *æther*. But for the ſatisfaction of ſuch readers as might not wiſh to be troubled with a full examination of this author's works, I ſhall quote a few of thoſe paſſages wherein the author himſelf fixes the meaning of the terms he uſes, and determines the real ſcope of his inveſtigations with more clearneſs and preciſion than all his commentators, interpreters, and panegyriſts have done.

The ſenſe of every author is collected from his own definitions, and, I hope, Sir Iſaac Newton will be allowed capable of forming juſt and accurate definitions of his own meaning. His centripetal force, then, of which he treats throughout a great part of the two firſt books of his *Principia*, he thus defines. Def. 5. *A centripetal force is that by which bodies are drawn, impelled, or any ways tend towards a point as to a centre.* Some perſons have cenſured this definition as if confounding ideas really oppoſite, and leaving the force defined ſtill vague and undetermined. But they ſeem not to have comprehended the ſcope of the definition, which was only to determine, not the nature of any force, but the ſenſe in which the author uſed the words *centripetal force:* and this it certainly does; for from it we underſtand, that wherever he uſed the words *centripetal force,* he neither meant a *drawing force* in particular, nor an *impelling force* in particular, but *any force*, whereby bodies might tend towards a centre, whether the power acted from within or without. The author further explains his meaning in the illuſtration of the eighth definition: ‘I uſe the words *attraction*, *impulſe*, or *propenſity* of any ſort towards a centre *promiſcuouſly* and *indifferently* one for another, conſidering thoſe forces, not *phyſically*, but *mathematically*. Wherefore, the reader is not to imagine, that by theſe words I *any where* take upon me to determine *the kind* or *the manner* of any action, the cauſe or the phyſical reaſon thereof, or that I attribute forces in a true and phyſical ſenſe to certain centres (which are only mathematical points), when at any time I happen to ſpeak of centres as attracting or endowed with attractive powers.’ Theſe two paſſages clearly ſhew that the deſign of the foregoing definition; and of the many explanations of his terms, which he interſperſes throughout his works, was to caution his readers againſt underſtanding as *real cauſes* thoſe forces, which he aſſumed in idea, and againſt deducing the nature of the forces aſſumed, or inveſtigated from the arbitrary names he made uſe of to expreſs them. To prevent which miſtakes, he here declares, that he does not *any where* determine *the kind* or *the manner* of any action, more particularly that of attraction or gravity, which is the action he principally treats of.

But this, if poſſible, he more clearly intimates in the concluſion of the 11th ſection. (L. 1ſt. Princ.) ‘I here uſe the word attraction in general for any endeavour, *of what kind ſoever* made by bodies to approach each other, whether that endeavour ariſe from the action of the *æther*, of the *air*, or of any *medium* whatſoever, whether *corporeal* or *incorporeal*, impelling bodies placed therein towards each other. In the ſame general ſenſe I uſe the word impulſe, not defining in this treatiſe the ſpecies or phyſical qualities of forces, but inveſtigating the quantities or mathematical proportions of them, as obſerved before in the definitions. In mathematics we are to inveſtigate the quantities of forces with their proportions conſequent upon *any conditions ſuppoſed*; then when we enter upon phyſics we compare thoſe proportions with the phænomena of nature, that we may know what conditions of thoſe forces anſwer to the ſeveral kinds of attractive bodies.’ Nothing can be determined with greater preciſion and more reiterated caution than the author's deſign throughout his *Principia*, and the ſenſe in which his terms are to be underſtood. He here declares, that in the treatiſe he was then writing, *viz.* the *Principia*, that treatiſe being entirely mathematical, he by no means defined *the kinds* or *phyſical qualities* of the forces aſſumed, but ſimply inveſtigated their qualities or mathematical proportions on the conditions ſuppoſed, or, in his own words, conſequent on the data aſſumed, alledging that it was the ſole object of a mathematical work, ſuch as he had in hands, to determine the proportions of the forces aſſumed; according to the conditions ſuppoſed, or the data aſſumed, it being reſerved for phyſical inveſtigations to determine which of theſe forces, thus mathematically computed, really exiſted, and acted in bodies, and what was the *kind*, or, in other words, the *mode of operation* of thoſe forces. He is equally explicit in the beginning of the the ſame ſection, where he ſpeaks thus: 'I ſhall, therefore, at preſent go on to ſpeak of the motion of bodies mutually attracting each other, conſidering the centripetal forces as attractions, *though perhaps, in a phyſical ſtrictneſs, they may more truly be called impulſes*. But theſe propoſitions are to be conſidered as *purely mathematical*; and, therefore, laying aſide all phyſical conſiderations, I make uſe of a familiar way of ſpeaking, to make myſelf the more eaſily underſtood by a mathematical reader.'

From theſe and ſimilar cautions interſperſed throughout the two firſt books of the Principia, nay, from the tenor of all the propoſitions of theſe books, it is evident that they are purely mathematical, and only adduced to determine *in the abſtract*, what ſhould be the laws, the proportions, and the effects of certain forces arbitrarily aſſumed, to ſolve the phænomena of the planetary motions, conſequent on the conditions of the forces, the forms of the bodies, and the circumſtances of the medium given, without any relation to, or connection with the phyſical kind or mode of the centripetal force, attraction, or gravitation ſuppoſed. For I appeal to any mathematician, whether in the demonſtration of the 6th propoſition of the 1ſt book, which, with the firſt of the ſame is the foundation of all the theory of curvilineal motion; whether, I ſay, in this or any ſucceeding propoſition, it in the leaſt affects the demonſtration, to ſuppoſe the verſed ſine, which repreſents the impulſe of the centripetal force, to be produced by an *impulſe* from abroad, more than if the ſame were produced by a *check* from within. All that is neceſſary for the truth of the theory is, that whiſe the revolving body would have deſcribed the tangent of a certain arch by means of the projectile or the acquired force, it be deflected from that right line by ſome force directed to the centre, whether *attractive*, or *propulſive*, whoſe effect is expreſſed by the verſed ſine of the arch deſcribed. And it is for this reaſon that our illuſtrious author ſo often repeats the before cited obſervations; that it was not in the nature of his works to aſcertain the kind or manner of forces, but ſimply their ratios and the point of tendency.

In the 3d book of the Principia, indeed, our author no longer confines himſelf to pure mathematics; but begins to take a view of the phænomena of nature, in order to determine, whether the forces before mathematically aſſumed and computed, really correſponded with thoſe phænomena. He finds, in fact, that the laws and effects of the centripetal force juſt mentioned, really obtain in nature, and from the celeſtial appearances educes three primary propoſitions, *to wit*, that the forces by which the circumjovial planets are continually drawn off from rectilineal motions and retained in their proper orbits, tend to Jupiter's centre, and are reciprocally as the ſquares of the diſtance of thoſe planets from that centre—that the forces, which retain the primary planets, tend to the ſun, and are in a like inverſe duplicate ratio—and that the moon is retained in her orbit by a like force reſpecting the earth as centre—in ſhort, that the *force*, whatever be its nature, which retains all the planets, whether primary or ſecondary in their orbits, obſerves the laws of the centripetal force computed in the preceding books. And in the three following propoſitions he ſhews, that this centripetal force muſt be the ſame with gravity, whereby bodies deſcend to the earth; and thence proves, that there is a *power of gravity* tending to all bodies proportional to their ſeveral quantities of matter. By means of which power, throughout the remainder of his elaborate work, he gives mathematical ſolutions of many of the moſt difficult and curious aſtronomical phænomena. But *what this gravity is*, whether it be an attractive power bodies are endowed with, or a foreign impulſe exerted upon them, he decides not, nor even examines. For no ſingle problem or theorem is adduced throughout all Newton's works for determining *the nature*, *the reſidence*, or *mode of operation* of this power. On the contrary, he always acknowledges himſelf in doubt and ignorance with regard to this matter; inſomuch, that after finiſhing his principia and his opticks, he declares that what he called attraction might in reality be impulſion. His words are theſe (ſee 31ſt Q.) 'What I call attraction may be performed by impulſe or by 'ſome other cauſe unknown to me. I uſe the 'word here to ſignify only in general any force 'by which bodies tend towards one another.'

And hence it is that thoſe writers, who examined maturely and rightly comprehended Newton's works, have not repreſented attraction as a cauſe of phænomena, but as a word expreſſing the phænomenon of tendency itſelf, the law of which tendency is computed by Newton, but its cauſe not aſſigned. 'It is 'very unreaſonable, ſays Doctor Clark, (p. 335) 'to call attraction a miracle and an unphiloſophical term, after it has been ſo often diſtinctly declared, that by that term we do not mean 'to expreſs the cauſe of bodies tending towards 'each other, but barely the effect of this cauſe, 'or the phænomenon itſelf diſcovered by experience, whatever be or be not the cauſe of it. 'Gravitation or attraction in this ſenſe is an actual phænomenon in nature.' The ſentiments of Mr. Rouning another eminent Newtonian, are exactly the ſame. ‘It is to be obſerved, ‘ſays he, (V. 1ſt, p. 17), that when we uſe the ‘word attraction or gravitation, we do not ‘thereby determine the phyſical cauſe of it, as ‘if it proceeded from ſome ſuppoſed occult ‘quality in bodies, but only uſe theſe terms ‘to ſignify an effect, the cauſe of which lies ‘out of the reach of our philoſophy.’ And Monſ. Maupertuis, the French academician, who is certainly no mean interpreter of Sir Iſaac Newton's meaning, makes this declaration in defence of attraction. ‘Men's minds ‘have greatly revolted at the word attraction, ‘many were afraid that they ſhould ſee the ‘doctrine of occult qualities revived in natural ‘philoſophy. But to do juſtice to Mr. New‘ton, he never conſidered attraction as an ex‘planation of the gravity of bodies towards ‘each other. He has often remarked that he ‘uſed this term to ſignify an effect not a cauſe.’ Nevertheleſs, moſt of our preſent authors and teachers, tho' profeſſing to derive from Newton all their philoſophical tenets, and to deliver the genuine knowledge of the Newtonian ſyſtem, not only determine the mode of operation of that attraction, which he left unſettled, but alſo erect into a natural cauſe a phænomenon, which Newton judiciouſly treats as an effect, the cauſe of which he declares remained ſtill to be diſcovered by experimental philoſophy. There are, ſays he, (Opt. p. 369.) agents in nature capable of making the particles of matter ſtick together by very ſtrong attractions, and it is the buſineſs of experimental philoſophy to find them out. But this was a branch of ſcience our renowned geometrician did not much cultivate, except in his opticks alone, where however he was far from conſidering his phyſical principles as ſufficiently proved, for he concludes by propoſing them as queries and ſubjects yet to be inquired into and determined. It muſt be allowed indeed, that many of the more modern writers, in ſpeaking of attraction, adhere to the ſenſe of Sir Iſaac, which is accurately diſtinguiſhed by Dean Hamilton, in his lectures introductory to natural philoſophy (p. 33). 'Though the beſt philoſophers 'have agreed in calling theſe forces by the 'names of attraction and repulſion, yet they 'intend thereby only to denote certain cauſes 'or powers, whatever they are that produce 'well known effects not to *expreſs* the nature of 'thoſe cauſes, or the *manner in which they operate.* 'And as there is a manifeſt convenience in

'having names for theſe general cauſes which
'muſt be ſo often mentioned, to object to theſe
'words is but diſputing about names without
'conſidering the proper ſenſe, in which theſe
'words are to be taken; for we may conſider
'theſe words *till their cauſes are found out*, as
'powers and qualities, with which bodies have
'been endowed for carrying on the operations
'of nature.'

This writer diſcovers a penetration, and at the ſame time a modeſty conformable to the ſpirit of Sir Iſaac Newton, who never attempted (like ſome of his unſkilfull followers) to impoſe the word or idea of attraction on the world for a real cauſe; but propoſed it barely as a diſtinctive term to mark the object of our ſenſes, and ſerve as a *datum* for mathematical calculation. For until the cauſe of the phænomena is diſcovered, it is of great uſe to employ a ſubſtitute, tho' but ideal as a baſis for geometrical operations. Nor can this produce falſe concluſions, as the term is confined to expreſſing the force whereby bodies approach, without any regard to the real agent or mode of action, whether it be that of drawing or impelling, no more than the aſſumption of x to deſignate an unknown number, or the thing ſought can render the algebraic operation erroneous. On the contrary, this facilitates the procedure, and whenever the real quantity is found out, its value may be ſubſtituted in any ſtep of the operation, and whatever was true of x while the quantity was unknown, will be alſo found true of it, when diſcovered and determined. So alſo whatever ratio, computations, or geometrical properties are now found applicable to the idea of attraction, will be true of its mechanical cauſe, whenever it ſhall be diſcovered, as we have partly ſeen in the preceding ſection.

But a great advantage attends the acknowledgment of the true import of this fictitious name; for it marks the preciſe bounds of our phyſical knowledge, ſhews where the imperfection of our preſent ſyſtem lies, opens a viſta, and excites the emulation of minds capable of ſuch inveſtigations, to ſearch out the latent cauſe. And this was preciſely the ſtate Sir Iſaac left philoſophy in; for having given full perfection to his geometrical works, he pointed out the *deſiderata* that then remained for the perfection of philoſophy, by propoſing all his phyſical principles as queries, and giving his own conjectures concerning them, to be confirmed or corrected by future philoſophers.

What has been here ſaid is ſufficient to rectify the conceptions of ſtudents, who are ſeldom aware of the true and ſtrict import of the fundamental principle of the philoſophy they are learning; it will alſo ſerve to ſilence the clamours and remove the apprehenſions of perſons more deeply learned, but who have often more of zeal than diſcernment in their philoſophical tenets; and finally, it will illuſtrate the deſign of the following inquiries which are inveſtigations of the real and univerſal cauſe of attraction in all its various branches, *to wit*, gravitation, coheſion, electricity, &c.

SECTION III.

Attraction, with thoſe who Treat it as a Cauſe, is a Principle confuſed and obſcure, and without any real Foundation in Nature. The true Principle of all Attractions inveſtigated and determined.

CERTAINLY every one will allow that an univerſal power, repreſented as the ſole phyſical agent and main ſpring of the planetary motions, and of every other mechaniſm in nature, ſhould not be paſſed over careleſly, nor taken on the word of any author, for two great reaſons: 1ſt, becauſe its importance in nature ſhould render it a chief object of phyſical inquiries; 2dly, becauſe its univerſality throughout all parts of the creation ſhould render its exiſtence obvious, and its nature diſcernible in the moſt common occurrences and moſt uſual opperations of nature. We will not therefore be content with ingenious conjectures, far-fetched experiments, or obſcure explanations of this principle. It is not philoſophers we muſt conſult, but nature herſelf; and let her anſwer, not in the forced language of particular experiments, but in the ſpontaneous reports of common experience. We ſhall conſider indeed, what conception of attraction philoſophers form; but we ſhall not ſtop here, we ſhall inveſtigate the notion which nature herſelf authorizes us to conceive, and really impreſſes in her known opperations.

Mr. Martin, whom we quote as a compiler of the beſt authors on phyſical ſubjects, and therefore a proper voucher for received tenets, gives us the following idea of the Newtonian attraction, (Philos. Brit. vol. 1. p. 15). 'Hence we have 'no reaſon to doubt, but that all kinds of at'traction conſiſt in fine imperceptible particles 'or inviſible effluvia, which proceed from every 'point in the ſurface of the attracting body in 'all right lined directions every way, which in 'their progreſs lighting on other bodies, urge 'and ſolicit them towards the ſuperiour attract'ing body. Therefore, the force or intenſity 'of the attracting power in general muſt al'ways decreaſe as the ſquare of the diſtance 'increaſes.' Mr. Ferguſon, in his aſtronomy, propoſes other ideas of attraction. ‘ Gravity, ‘ he ſays, (p. 59), ſeems to ariſe from the agency of ſome ſubtile matter, preſſing towards ‘ the ſun and planets, and acting like all mechanical cauſes by contact. But on the other ‘ hand, when we conſider that the degree or ‘ force of gravity is exactly in proportion to ‘ the quantity of matter in thoſe bodies, without any regard to their bulks or quantity of ‘ ſurface, acting as freely on their internal as ‘ their external parts, it ſeems to ſurpaſs the ‘ power of mechaniſm, and to be either the ‘ immediate agency of the Deity, or effected ‘ by a law originally eſtabliſhed and impreſſed ‘ on all matter by him. But ſome affirm, that ‘ matter, being altogether inert, cannot be impreſſed with any law, even by Almighty Power; ‘ and that the Deity or ſome ſubordinate intelligence muſt therefore be conſtantly impelling ‘ the planets towards the ſun, and moving them ‘ with the ſame irregularities and diſturbances, ‘ which gravity would cauſe, if it could be ‘ ſuppoſed to exiſt. But if a man may venture ‘ to publiſh his own thoughts, it ſeems to me ‘ no greater abſurdity to ſuppoſe the Deity capable of infuſing a law, or what laws he 'pleaſes into matter, than to ſuppoſe him capable of giving it exiſtence at firſt.'

Without conſulting any other authors, we have here four conceptions of attraction diſtinct from each other, and entirely ſubverſive of each other. Some will have it to proceed from an imperceptible effluvium which bodies throw forth from every pore, and thereby catch hold of other bodies and draw them in. Others think the phænomena of attraction proceed from the impelling force of ſome medium tending to the ſun, planets, and other bodies; and this idea was not entirely rejected by Newton, though few of his followers ſeem to reliſh it. A third claſs of philoſophers reject all ſecondary cauſes of attraction, and diſpenſe themſelves from the trouble of explaining its cauſe, or inquiring after it, by affirming it to be a law originally ſtamped upon all matter. And the ingenious writer alluded to by Ferguſon, in his inquiry into the nature of the human ſoul, conſiders ſuch a law as inconſiſtent with the inertneſs of matter, and therefore will have every action, motion and operation of matter to proceed from an immediate interpoſition of a ſpiritual being. How obſcure therefore and complicated is the preſent philoſophy, when viewed in a phyſical light! The learned and the ignorant equally know that there is a mutual tendency between bodies, which the learned ſtile attraction, but as to the cauſe of it, which is the object of philoſophy, they are equally in the dark. And after the ſtudy and labours of ſo many eminent philoſophers as wrote on this ſyſtem, ſo great is the obſcurity of its phyſical principles, that it has not all this time been determined, whether the moving forces ariſe from an attracting effluvium or an impelling medium, whether they be mechanical or preternatural, material or ſpiritual.

We agree with Ferguſon, that it is an abſurdity to deny that the Creator of ſubſtances could give powers and properties, *i. e.* laws of action to matter, which otherwiſe would have been inert. This is evident from fact, for theſe active powers exiſt in matter, therefore they were imparted to it by the Creator. And the poſſibility of it may be deduced from the principles of him who denies it; for that author who excludes all active powers from matter, is obliged to explain all its actions and motions, either by the interpoſition of the Deity or of a ſubordinate ſpirit. Now the ſpirit ſuppoſed does not certainly produce the preſent motion of matter by touch, but by an efficacity of will; but it appears no more repugnant that the will of a ſpirit ſhould produce action or motion of inert matter for a length of time, than for a ſingle inſtant; therefore the Omnipotent Will of the Creator at leaſt might at the Creation have determined matter to an action and propenſity, while the world was to exiſt. But indeed, to ſay that matter continues inert, after ſuch a law of action is impreſſed on it, is what implies the abſurdity, for it is contradictory that matter ſhould be invariably determined to a certain mode of action, and endowed with a power not only of moving but of impelling other matter, and at the ſame time be indifferent to reſt or motion.

The univerſal inertneſs of matter, is a principle derived from the atomic philoſophers, which more modern philoſophers now apply to their particles of matter; and this property of inertneſs being allowed on all hands becomes a fixed tenet, and enters into mens idea of matter; whence perſons reared in this perſuaſion look upon activity as inconſiſtent with the nature of matter, and affirm, that giving activity to matter is rendering it ſpirit. But this prejudice is both raſh and inconſiſtent. It is raſh if it be not clearly founded in either *reaſon* or *experience*; and it is inconſiſtent if it be contradicted by either. Now, however philoſophers may diſpute about innate ideas of God or of moral precepts, they will ſcarcely pretend that we have any innate idea of matter, of which, notwithſtanding the uſe of our ſenſes, they confeſs we have a very inadequate idea. Conſequently, the inertneſs of matter is not founded in the light of reaſon. Experience then is to determine the point. Now, from experience we know that the flame of a candle, of fire, of gunpowder, and the light of the ſun, have not only activity in them, but ſuch power of action as excites motion in all other kinds of body. And light is a material ſubſtance, ſince it affects our corporeal organs, is ſubject to reflection and refraction from other matter, and is a transformation of groſs bodies; therefore ſome matter is active. The activity of matter is equally ſenſible in fermentation, vegetation, &c. in fine in all operations of nature, for which ſee Lec. 2. part. 1. Therefore experience, far from authorizing the univerſal inertneſs of matter, proves it falſe and inconſiſtent; and as for revelation, it is no where its object to inſtruct men in the properties of matter, nor do I know any paſſage of ſcripture which affords proper grounds for adopting this tenet.

One thing which contributes to confirm men of learning and abilities in an obſtinate adherence to the principle of inertneſs, is their pious apprehenſions for the ſpirituality of the ſoul, joined to a ſtrong attachment for their early opinions. But it ſeems ill-judged to make the ſpirituality of the ſoul and the inertneſs of matter embark in the ſame bottom; for the inertneſs of all matter cannot fail of being doubted and rejected, and if united with the ſpirituality, would diminiſh its certainty; whereas, if properly treated, the ſpirituality of the ſoul is independent of the inertneſs and activity of matter, and ſupported on the moſt unqueſtionable grounds; for the powers of *reaſon*, *ſelf-conſciouſneſs*, *reflection*, and *election* are found the more inconſiſtent with matter, the more we underſtand its activity, and diſcover the ſimple predetermined propenſity, with which alone it is endowed.

Since then the univerſal inertneſs of matter ſo embarraſſes philoſophers in accounting for the operations of nature, why ſhould they longer inſiſt on that torpid quality? For in reality the tenet is inconſiſtent with nature, unleſs ſome powerful intelligence be ſuppoſed to attend and actuate each body. The flame of a candle, and every flame in the univerſe has a power of throwing forth its light and heat on all ſides, which we call expanſion. Now, would it not be more conſonant to phænomena and to reaſon to allow it not to be inert, than to ſay an intelligence attends and actuates every candle and fire in the world, or even thoſe of each town or each province? Or, if it be ſaid that the Supreme Being actuates all by his univerſal influence and providential care, muſt we admit a reiterated act of the Divine Will for every ſpark that ſpirts from a fire, for every body that falls to the earth, and for every inflection a planet gets in deſcribing its orbit. Indeed that man, whoſe ſoul is the image of God, and who is by nature conſtituted Lord of the Creation, ſhould be under the guidance and direction of a ſuperiour intelligence; that provinces and nations ſhould have their protecting ſpirits, and even that children ſhould have guardian angels appointed for them on entering into the world, is as conformable to reaſon, as it is authenticated by ſcripture. For all theſe being moral and free agents, are to be influenced and acted upon, not by the rigid neceſſity of unchangeable laws, but by the conviction of reaſon or the incitement of deſire. But matter or body, being incapable of election, is invariably ſubject to the phyſical propenſity originally ſtamped upon it by the Creator's primitive and eternally efficacious will. To ſay that every ſpark that iſſues from a fire, that every body that falls to the ground, &c. is influenced by a ſubordinate intelligence, or by repeated acts of the Divine Will, is unphyſical and derogatory of Divine Majeſty; becauſe it is contrary to the proofs we every where behold of the univerſe being regulated by great and ſettled laws; and ſuch trifling acts (according to the conception he has given us of a Wiſe Providence, and according to the uniform effects of it, which the univerſe diſplays) arraign the Divine Wiſdom and Power, which could as eaſily form the great and univerſal ſprings of nature we have mentioned as form an animal or inſect. (See Lecture 1). Is it not conſiſtent with the infinite Majeſty, Power and Wiſdom of the Deity, to have given one unchangeable and powerful faculty of action, viz. expanſion to to the light he created to enliven and actuate all other matter, and be a mean ſpring in nature's operations? And as this diffuſive principle alone would be deſtructive to nature and incapable of performing her various operations, was it not alſo conſonant to Infinite Wiſdom to have created another principle of oppoſite eſſence, *to wit*, convergent, ſo vaſt in quantity, and powerful in agency, as to counteract the former, and anſwer all the purpoſes of nature, as deſcribed in our 8th and 9th lectures? And in the third place, is it not more conformable to the Divine Oeconomy diſcovered throughout nature, to ſuppoſe, that the Creator hath formed the firmament or frame of nature to bind and compact the great machine of the univerſe, actuated by theſe two great ſprings of action, than to have left the bodies of nature diſperſed thro' an infinite void, without a material link of union, phyſical principle of action, or any mechaniſm except geometrical laws and ratios, which are mere modes of motion, not cauſes?

As for the other claſs of thoſe who inſiſt that the planetary motions and all the phænomena which are the object of philoſophical inquiry, ariſe, not from the inſtrumentality of material agents, but from the force of an abſtract law, they depart from all analogy, account for natural effects by metaphyſical ideas, and inſtead of ſearching after real cauſes, baniſh them out of the univerſe, and feign a ſyſtem either to favour their indolence, or cover their ignorance of real cauſes. To ſuch a ſyſtem as this the remarks of Sir Francis Bacon ſeem very applicable: 'Aſtronomy (ſays he, Phyſics, Sect 4.) is now like the 'ſacrifice Prometheus would have impoſed on 'Jupiter, *to wit*, a fair large hide ſtuffed with 'ſtraw, leaves and twigs, inſtead of an ox. So 'aſtronomy gives us the number, ſituation, 'motion and periods of the ſtars, as a beautiful 'outſide of the heavens, whilſt the fleſh and 'entrails are wanting, that is, a well fabricated 'ſyſtem, or the phyſical reaſons and foundations 'for a juſt theory that ſhould not only ſolve 'phænomena, as almoſt any ingenious theory 'may do, but ſhew the ſubſtance, motions, and 'influence of the heavenly bodies as they really 'are.—Enquiries of this kind have hitherto 'been ſcarcely touched upon, but the chief 'pains have been beſtowed in mathematical 'obſervations and demonſtrations, which indeed may ſhew how to account for all theſe 'things ingeniouſly, but not how they actually 'are in nature.' Even after all the mathematical inveſtigations of Sir Iſaac, ſuch was evidently the ſtate of philoſophy, as we have ſeen from his own declarations, for he confeſſed himſelf totally unacquainted with the phyſical cauſe, or even mode of the agent which he ſupplied by the aſſumed idea or name Attraction. How little his followers have improved on his labours, appears from their various and diſcordant conceptions of attraction. Indeed, there is one thing that ſeems to give a great ſanction to this ideal philoſophy, *to wit*, that gravity is in proportion to the quantity of matter in body, and not as its magnitude or quantity of ſurface. This they conſider as irreconcileable with any mechanical cauſe, and therefore, without further inquiry ſit down content with ſolving all phænomena by original laws. But there is great difference between a thing being impoſſible and being unknown. And, while ſo great a part of nature as falls within our knowledge is regulated by the moſt ſublime and beautiful mechaniſm, our ignorance with regard to gravity ſhould not authorize us to pronounce it miraculous or immaterial. But this deſideratum ſhall be phyſically ſolved, when we come to explain gravitation, and conſequently the ſole foundation of this opinion removed. We have now to conſider the two opinions which alone attempt to aſſign a material cauſe of attraction, or render its mode of operation intelligible, according to phyſical principles.

Attraction ought to mean, and, as we have ſeen, really means in the general acceptation of philoſophers, a ſucking or drawing power, whereby bodies mutually approach, if at a diſtance, and cohere, if in contact. To fix our ideas and illuſtrate the ſubject, I ſhall lay down two examples that exhibit the appearance of natural attraction as ſtandards to refer to. Animals have a power of inſpiration and ſucking, which proceeds from their being furniſhed by the author of nature with a well contrived recipient, equipped with proper valves, and from their being endowed with a power of contracting and enlarging its dimenſions, or of excluding its contents in order to repleniſh it anew. To draw in air, the lungs, which are then the recipient, are diſtended by an expanſive power peculiar to animals; and thus a vacuum being formed, or at leaſt a ſpace where the air is not ſo denſe as abroad, that fluid is preſſed in by the ſuperiour preſſure of the atmoſphere. The drinking or ſucking in of any other fluid is alſo performed by the ſame operation, which is reducible to two parts, viz. the power of the animal to diſtend the recipient, and the tendency of fluids to an equilibrium, whereby their parts are preſſed into vacant ſpaces on account of the inferiour reſiſtence there experienced. To this ſtandard we muſt refer the ſucking of blood by a leech, the drinking through a tube, the raiſing of water in a pump, and many other inſtances which it is unneceſſary to enumerate. All that requires to be remarked is, 1ſt, the neceſſity of a recipient with its apparatus, and of a power of diſtending and contracting, or opening and ſhutting, which is common to animals, and which in the pump is ſupplied by an artificial contrivance and an external force; all which only ſerve to form, as it were, ſome kind of vacant ſpace for the fluid to flow into; 2dly, we muſt take notice, that the riſe or entrance of the fluid into the recipient is not occaſioned by a drawing in the recipient, but by a preſſure of its own parts, or of ſome other body or fluid which acts on it; and laſtly, that the operation muſt ceaſe as ſoon as the recipient is full, unleſs it has a power of excluding what is taken in, or condenſing it into a ſmaller ſpace, ſo as ſtill to leave room for more. The former is the caſe in breathing, or in a bellows, which drives through the pipe what it takes in at the valve; the latter is the caſe in the air-gun, and where neither exception takes place, as for inſtance, when a leech is full, attraction ceaſes, and the creature falls off. And all animals ceaſe to drink, when their bellies are full, except ſuch as paſs it as faſt as they drink as the bellows do the air, or the pump the water it raiſes: and this is one general ſtandard of attraction.

I ſhall now give a ſecond: Seeing once a number of ſpiders on a dry bank, I reſolved to be convinced of the great power of projecting their threads, which I had heard attributed to theſe inſects. Fixing therefore my ſtick in the central part of a ſmall pool, with an inch or two of the head over water, I placed a ſpider upon it. The creature walked round the head of the ſtick down to the water on every ſide, and up again, but not finding any dry paſſage over the water, he at length ſettled on the top, and projected a thread horizontally toward each ſide, theſe not coming to the brink or lighting on any thing they could ſtick to, he raiſed his bomb to various elevations, and diſcharged his threads in every direction. At length, finding the extent of his diſcharges greatly to decreaſe, I concluded his power was almoſt ſpent, I therefore held a ſwitch at a moderate diſtance over him, which he perceiving erected perpendicularly and ſhot ſome threads in this direction. I think it was the ſecond or third, which caught the ſwitch, and adhered to it ſo ſtrongly as to bear his weight. Immediately he aſcended far more nimbly than a ſailor by a rope, and in a manner far more maſterly; for he reeled up his thread accordingly as he mounted; when he got to the ſwitch, I landed him ſafe.

If now we carry our views throughout all nature, we ſhall not find one ſingle inſtance of drawing or attraction, which is not performed by the mechaniſm diſplayed in thoſe two examples, or one immediately correſponding. I do not mean by inſtance a remote phænomenon, nor an obſcure experiment, which is not underſtood, I mean a fact or operation diſcernible to ſenſe, under the eye of experience and conformable to the conſtant laws we ſee nature obſerve. Nay, if men's minds had not been blinded by a prejudice for myſterious tenets, or led aſtray by miſconceptions, any mode of attraction different from thoſe would have been conſidered as inconceivable, phyſically impoſſible, or repugnant. Let us examine our ſtandards.

Suction, or drinking, is one of the known phænomena which gives the cleareſt idea of attraction. But in both, according to what we ſee and feel, and according to the unanimous voice of philoſophers, there is nothing, except a muſcular exertion of elaſticity to form a recipient and a preſſure of ſome fluid into the vacated ſpace. The ignorant, indeed, imagine that there is ſome power in the throat of drawing in air, water, &c. but thoſe, who have received any tincture of philoſophy, know, that in drinking the liquid, being raiſed above the throat, and then poured in, falls into the ſtomach, as it were into a vacuum, both by it's own gravity, and the preſſure of the atmoſphere. Air alſo is inſpired by its own preſſure, when the lungs rarify or exclude what they had taken in before. By the ſame principle the fire apparently draws the air, which is preſſed into it, when what was before contiguous is rarified or conſumed, and the cupping glaſs apparently draws the part of the body to which it is applied, tho' in reality that part is preſſed into it by the elaſtic principle within, when the air in the glaſs is rarified by flame. In ſhort, in all theſe inſtances a mechanical or conſuming cauſe adapted to deſtroy that univerſal balance, in which only the parts of the ſame fluid can reſt, is the great and univerſal principle of motion in them, and in this ſpecies of attraction; and therefore no body can be ſaid to attract in this manner, but ſuch as is endowed with a power of rarifying a ſpace by repeatedly compreſſing, excluding, or conſuming what it there receives in order to make room for more; and then the motion that enſues really ariſes from preſſion.

In the other ſtandard the whole operation was performed by a firm link of union between the drawing and drawn bodies, and the elaſtick exertions of the members and body of the inſect, all which were ſo neceſſary for the effect produced, that without theſe cauſes, or without any one of them, the effect would be juſtly eſteemed a miracle, that is, contrary to the known laws and uſual operations of nature. For it is as repugnant to our knowledge and ideas of the powers of nature, that a ſailor ſhould pull himſelf up, or draw a diſtant body towards him without a rope or link, and without bodily exertions, as it is that the ſame man ſhould move a mountain by ſpeaking to it, or walk on water, which acts and operations are ſupernatural. If therefore analogy be of any weight in phyſicks, we muſt conclude there is no *drawing* throughout the univerſe which is not performed by *links*, *graſping* and *muſcular exertions*, or by a *recipient* and *preſſive medium*, or at leaſt by a mechaniſm ultimately coinciding with theſe. And this concluſion is not only eſtabliſhed on analogy, but confirmed by the light of reaſon. For if we look into our own ideas, it is in vain we ſhould endeavour to conceive a drawing without hands, links, &c. or a ſuction without lips, lungs, valves, or a rarifying power. We may indeed, by abſtraction, as Newton has done throughout his works, attend ſolely to the approach of two bodies, without conſidering the cauſe; but if we imagine a drawing a concomitant, and neceſſary mechaniſm will immediately preſent itſelf to the mind. Therefore, to attribute ſuch a power of drawing to matter, which at the ſame time is ſuppoſed inert, is a contradiction; ſince attraction or drawing ſuppoſes conſtant action, which is the reverſe of inertneſs; and tho' matter was not inert, ſuch a power would be inconſiſtent with it, unleſs each particle were furniſhed with lips, lungs or valves for ſuction and a power to rarify, or elſe equipped with hooks or fingers to draw by, and a power of diſtending and contracting them. How ſtrange then, confuſed and inconſiſtent the opinions of ſome writers on philoſophy!

If the ſpider we have mentioned could ſhoot his viſcous ſubſtance from every part round his body as conveniently as he does from one, and could again reel up the numberleſs threads he had thus emitted, it would enable us to form ſome conception of the firſt opinion concerning attraction, *to wit*, how an attracting body emits its effluvia from every point in diverging rays, ſo as to catch diſtant and neighbouring bodies and draw them to itſelf, and alſo how contiguous particles or bodies by an action of this kind might firmly cohere. But, even did animate nature afford an inſtance of attraction at once ſo wonderful and ſo favourable to that theory, would not a philoſopher be deſervedly laughted at, who would attribute ſuch an extraordinary power to inanimate bodies, to every ſtick and ſtone, to the earth and to the ſun?

How prodigious ſhould be the power of the ſun to propel his attractive effluvium to Jupiter and Saturn! How tenacious and denſe ſhould this effluvium be to bridle ſuch bodies at thoſe immenſe diſtances, to curb their centrifugal *momenta*, and to keep them within their reſpective orbits! A ſtone whirled in a ſling has a centrifugal force proportional to its velocity and quantity of matter, to which the centripetal force, *i. e.* the ſtrength of the ſtring muſt be equal; what kind of cable then could bridle the centrifugal force of the earth or Jupiter, which is many thouſand times greater, and retain them within their orbits? I ſay nothing of the interruptions theſe cables would occaſion to the revolutions of ſecondary and inferiour planets, or of their powers of ſtretching and contracting at Aphelion and Perihelion. In ſhort, the puerility of ſuch conceptions, whether examined with regard to the great bodies of nature, or the minute particles of matter, renders a further diſcuſſion of them inconſiſtent with the gravity of a philoſophical treatiſe.

One conception of attraction more remains, *to wit*, that which explains the mutual tendency of bodies by the impulſion of an univerſal fluid. Attraction in our firſt ſtandard, *to wit*, that of ſuction is in reality, as we have remarked, performed by impulſion. However, the aptitude of conſtruction in the recipient, with the power of compreſſing, evacuating, or of rarifying, &c. which we have obſerved neceſſary in animals, the cupping glaſs, &c. could not be attributed to inanimate matter, without falling into the abſurdity we have juſt now condemned in others. But inanimate nature in her ſpontaneous operations alſo exhibits this mode of action, which is reducible to two parts, *to wit*, a rarifaction or conſumption of a fluid in a given body or ſpace, and a conſequent influx of the ſame fluid from the denſer part to reſtore equilibrium. This is the principle of action in the tendency of air and light bodies into fire. The ſame is the mode of operation in the apparent attraction of the cupping glaſs, in drinking, ſucking, breathing, &c. The operation in all theſe caſes is performed by the preſſure of the atmoſphere, or of other fluids: which together with what has been ſaid of all other conceptions of attraction, is a general proof that the phænomena apparently exhibiting attraction, do in reality proceed from impulſion, the principle of which we ſhall now lay down.

The celeſtical matter would be at reſt in all parts of the vaſt expanſe, were not the ſun and other conſuming bodies placed therein, which by their conſumptive power aſſimilate it to their own nature as a nutriment for their maintenance. But this act of aſſimilation being a transformation of ſubſtance, or the deſtruction of one ſubſtance for the generation of another, ſuch as every day occurs throughout nature, cauſes an actual rarifaction thereof, which immediately deſtroys the general equilibrium, and reſiſtence being there loſt, where the rarifaction is made, the ambient fluid muſt preſs into the rarified ſpace, and be followed by the remoter parts, all which move to reſtore the equilibrium. And if the elaboration continues, ſo as to render the aſſimilation of this fluid ſucceſſive and conſtant, a perpetual and ſucceſſive rarifaction of this fluid will be continued in the transforming body, in which caſe there will be a conſtant and ſucceſſive flow of this alimentary matter to the body from all ſides, like that of air to a conſuming fire.

Now, ſince all compound bodies contain their fires, which are elaborative and conſumptive of this matter, there will be a conſtant rarifaction of this matter in every one of theſe as well as in fiery bodies, tho' not ſo powerful: and therefore the celeſtial matter will preſs into them from all ſides, and in its paſſage will preſs other matters, as light, air, water, &c. into their conſtitution; which will cauſe a motion and apparent attraction of all ſuch light bodies as are viſible, and fall within the influence of that motion. Thus light is preſſed into bodies by a perpendicular preſſure of this fluid, which is the cauſe of refraction; and the ſame force will make water and other liquids ſtick to bodies, which is aſcribed to attraction, but which is really performed by the mode of ſuction *when rightly underſtood.* But before we enter into theſe effects, let us further illuſtrate the principle of conſumption and aſſimilation, by premiſing a few phyſical lemmas to form a theory.

LEMMA I.

IF a body is by nature conſumptive or effuſive of its ſubſtance, that its vigour, powers and magnitude be preſerved, it muſt be ſupplied with nutriment; and the quantity of its nutriment duly aſſimilated, muſt be as the quantity of its effuſions in a given time. For the body being effuſive, its ſubſtance would be diminiſhed; therefore its powers and magnitude would decreaſe; conſequently, to maintain it's powers and magnitude, the loſt ſubſtance muſt be continually repaired, *i. e.* the body muſt be nouriſhed in proportion to its effuſions. Therefore fire, wherever it ſubſiſts, requires a pabulum.

LEMMA II.

NOTHING can be nutrimental to body, but what is aſſimilable to its own ſubſtance; for *per* prop. 1. lect. 1. qualities are as their ſupporting ſubſtances; therefore, to reſtore the qualities and quantity of matter loſt by effuſion, the ſubſtance acquired muſt be the ſame with that loſt, *i. e.* the nutriment muſt be aſſimilated to the ſubſtance of the body it ſuſtains.

L E M M A III.

IF the pabulum of an effuſing body be a fluid, or reducible to that ſtate, and conveniently placed, it will flow into the conſuming body with a force and velocity proportioned to the conſuming power of that body.

For from the nature of fluidity, the parts of a fluid are at reſt, only while they are in equilibrio. But this equilibrium depends upon an equality of denſity and preſſure at all parts of the fluid, and an equality and ſufficiency of ſuſtainment around its bounds; either of theſe conditions being wanted, a motion will enſue to reſtore the equilibrium, and will continue until that is recovered. Now the conſuming body deſtroys the equilibrium under both reſpects; for its rarifaction and conſumption of a part deſtroys the equality of denſity, and takes away the ſuſtaining boundary on that ſide; conſequently the whole fluid muſt have a tendency to that part, to reſtore the equilibrium. And if the conſumption be conſtant, the greater and more quick it is, the more powerfully and inſtantaneouſly will the equilibrium be deſtroyed; conſequently the more copious and rapid will be the influx of pabulum.

Now, to exemplify and apply the foregoing theory, let the flame of a candle be the conſuming body. The ſurrounding air is a fluid, and the tallow is reducible thereto; and both muſt flow to the wick as long as the flame laſts; for the reaſons and in the manner aſſigned. The ſame may be ſaid of the ſun and the celeſtial matter which feeds it; for that is the fluid pabulum that ſurrounds the ſun. But this has been ſufficiently explained; for we have ſeen in the 8th lecture, that the ſun is a luminous body that effuſes its ſubſtance in the form of light; wherefore we concluded, that like all luminous bodies within our knowledge, it requires a ſuſtaining pabulum. One only inſtance can be thought an exception to this concluſion, *to wit*, the fire which ſubſiſts in the focus of a burning glaſs, ſeemingly without a pabulum to ſuſtain it, we ſhall therefore take it into conſideration.

This focal fire is either the atmoſpheric light revived by the action and preſſion of the ſolar beam, or a concentration of that, which immediately emanates from the ſun. In the firſt place, if the focal fire be the continuance and ſucceſſion of the ſolar effuſions, phyſically ſpeaking, we cannot conceive that at this immenſe diſtance from the ſun, ſuch detached parts of his ſubſtance can retain their vigour without a ſuſtaining pabulum, becauſe we find by experience, that ſparks that fly from burning bodies, vaniſh with the conſumption of the ſubſtance on which they lived, as does the flame of a candle or fire, when their fuel is exhauſted. Therefore, not having reaſon to think otherwiſe of this ſolar beam or its mode of ſuſtainment, we are to conclude from what we know and experience, that the detached parts of the ſun's ſubſtance muſt have a ſuſtaining pabulum like unto that, by which he is himſelf preſerved. On the other hand, if the focal flame conſiſts of the atmoſpheric fire revived by the action and preſſure of ſolar effuſions, can we ſuppoſe, contrary to experiment, that fires ſubſiſt there, or in any other body without a nutriment? Philoſophers, whoſe buſineſs it is to inveſtigate real cauſes, are not like the vulgar, to content themſelves with appearance alone, but in the inveſtigation of cauſes which are obſcure or remote, are to be guided by thoſe which produce ſimilar phænomena, and which are at once obvious to ſenſe and clear to the underſtanding. Therefore, p. 2d and 4th of Newton's rules cited, lect. 1. the known and familiar inſtances we have mentioned are to be our ſtandards in the interpretation of this phænomenon.

In our 4th and 5th lect. we have ſeen that the atmoſphere and all terreſtrial bodies contain their fires, which are for the moſt part accretions of the ſolar effuſions. Now, as thoſe latent fires manifeſt themſelves by ſparks, light, heat, and even flame, when excited by colliſion, friction, &c. we muſt conclude, that tho' dormant, they are ſtill alive, and therefore, being of a conſuming nature, p. lem. 1. require nouriſhment to preſerve their being. Beſides, as theſe concrete fires are detached parts of the ſolar ſubſtance, they require a pabulum for their preſervation analogous to that, which nouriſhes him. Now, all theſe bodies are within the ſpherical ſpace replete with the celeſtial matter, which emanates from the firmament to ſuſtain the ſun; being therefore immerſed in this fluid, it is convenient for their conſumption, and conſequently to be eſteemed the pabulum that ſuſtains their fires as well as thoſe of the ſun.

For theſe concrete fires of body muſt ſubſiſt either on the other internal concrete matters of the body, or ſome influent matter from abroad. But, whatever they ſubſiſt on, they muſt from the 2d Lemma conſume, otherwiſe it would not be nutrimental to them. If therefore they ſubſiſted on the internal parts of body, its texture and fabrication would be deſtroyed. Now ſince theſe continue good, it muſt not be by them, but by a fluid coming from abroad that the internal fires are fed; and this fluid muſt be the celeſtial matter, which as it is the pabulum of the ſun, being convenient, ought from the ſimplicity of nature to be the fuel of the ſolar ſubſtance, wherever it exiſts, whether in the heavenly ſpaces, or in the conſtitution of bodies. Now we have ſeen that all bodies contain their fires, that is, the accretions of light or ſolar ſubſtance which they have abſorbed during their growth and formation. Conſequently they are perpetually conſuming the celeſtial matter, which, together with the air and light it carries with it, muſt flow into them to reſtore the equilibrium of its parts, which is deſtroyed by theſe conſuming fires. For a perpetual waſte of this fluid is continually forming in bodies, which produces a reduction or kind of vacuum of this matter; whence ariſes the firſt principle of action and motion in all fluids to reſtore the equilibrium of their parts by a motion of the denſer parts to the rarer. Conſequently this fluid, and with it the ſolar light, in which all bodies are immerſed, preſs into them from all ſides in the form of centripetal ſpheres, to ſupply the loſs of denſity ſuffered within by the conſumption of their parts for the body's ſupport. The digeſted matter reſulting from this conſumption, emanates from bodies as we have remarked in the form of electric or elaſtic matter, which prevents the actual contact of bodies, and reflects light before it touches their ſurface. And the centripetal ſpheres, formed by the influx of theſe elementary matters, are the cauſes of the phænomena, which induced philoſophers to admit ſpheres of attraction about all bodies.

Thus the preſervation of bodies, and all their properties, with their motion and action, depend on the influences, aſſimilative powers, and other qualities of theſe two fluids. The ſimplicity of nature, the uniformity of their operations, and their univerſality throughout all parts of the material world ſhew them to be thoſe material agents, which in our 1ſt lect. we conceived to have been eſtabliſhed by the All-wiſe Creator in this magnificent machine of the univerſe, for exciting and carrying on the operations of nature without deficiency or danger of decay.' In works of human contrivance, the matter of the machine is ſubject to waſte and wear away, the ſprings relax, and the parts are diſcompoſed: but in this machinery conſtructed by the All-powerful Creator there is no waſte of materials, nor decay of powers. The quantity both of elementary and compound bodies remains the ſame, tho' undergoing their natural viciſſitudes; and the ſprings of action are permanent, being founded in the moſt ſimple principles of nature, *to wit*, the rarifaction and equilibrium of fluids.

LECTURE XII.

The Phænomena of Electricity, of the lunar Motions, of Tides, of Gravity and of Coheſion, clearly ſolved by our material Principles.

SECTION I.

General Properties of Electricity ſolved. Theory for the ſolution of extraordinary phænomena.

HAVING in the foregoing Section, by a philoſophical analyſis, inveſtigated the ſole conception and cauſe of attraction, to which the powers and nature of inanimate matter are adequate, we ſhall now examine that myſterious property, where it is moſt enlightened by experiment, that is in electricity. Electric attraction is that which ariſes in vitrious, ſulphurous, reſinous or any other kind of bodies when heated by friction. Its name is derived from *electrum*, having been firſt diſcovered in amber.

It is not our intention to give a compleat treatiſe on this ſubject, but to make a few radical experiments, which may take in the chief objects of inquiry in that branch of philoſophy. The phænomena in queſtion are now explained by electricians on ſuch various principles, as to introduce into philoſophy more cauſes than effects, which is contrary to the nature of ſcience; for principles ſhould be few, and at the ſame time ſimple and certain, and their application extenſive. Our interpretations ſhall be founded on the univerſal principles we have diſcovered, which being the real agents of nature ſhould ſolve all her phænomena. By a ſcientific application of theſe we hope to explain all the effects, which are now the object of philoſophical inquiry, from the moſt obvious to the moſt intricate phænomena of electrical attraction. The univerſality of our ſolutions, joined to their ſimplicity, and their conformity to the ſpontaneous operations of nature, will prove the utility, neceſſity, and certainty of our principles; for in real ſcience the truth of the eductions commonly reflects new confirmation on the principles.

An electrifying machine has a wheel, which turns a glaſs cylinder or globe under the preſſure of a rubber, by which it is excited, and a prime conductor which receives the electrical matter by ſharp metal points that are directed to the globe or cylinder. The conductor muſt reſt upon ſilk lines, glaſs, roſin, or ſome other *electric per ſe*, leſt the fluid which is to be therein accumulated, ſhould find a paſſage to the earth before it is ſufficiently collected to exhibit the phænomena. For, as the air is an electric, this prime, or any other conductor will be inſulated, *i. e.* the electric matter confined in it, when all communication with the earth is intercepted by electrics. When all parts of the machine are dry and wiped clean from duſt, the glaſs cylinder being warmed and ſet in motion by turning the wheel, and a communication formed between the machine and the earth, by an iron chain or ſome non-electric, that will conduct matter from the earth to the fricting ſurfaces of the glaſs and rubber, it will flow from thence by the wire points to the prime conductor, where it will ſoon accumulate to the higheſt degree the ſtate of the atmoſphere will admit of.

EXPERIMENT. I.

THE prime conductor being impregnated, approach it with the finger, knuckle or any other conducting ſubſtance, and luminous ſparks will iſſue forth with a ſnapping noiſe, each of which is called an exploſion. The greater they are, and the more numerous they are diſcovered from repeated approaches of this kind, after the wheel is ſtopped, the greater the degree of electrification, which is always greateſt in froſty weather. Light bodies preſented near the conductor, while thus impregnated, will be attracted, and the greater the electrification the greater diſtance will theſe bodies be attracted from.

That fire is collected in the prime conductor is evident by our lemma, lect. 4: from the exploſions; and that it was collected by friction, is alſo evident from the operation on the cylinder by which it is accumulated, which alſo agrees with former obſervations. For in our 5th lect. we ſaw that the colliſion of hard bodies produced ſparks of fire, that friction excites heat and kindles dry wood, that attrition in fluids makes them warm and produces light, therefore on the whole, fire hath been collected in the conductor. Now *per* lem. 2. lect. 11. Every kind of fire being effuſive of its ſubſtance muſt have a ſuſtaining pabulum, which pabulum, if it be a fluid, muſt, *per* lem. 3 to preſerve its equilibrium, have a conſtant influx into the body or ſpace containing the fire that rarifies and conſumes it. Hence the influx of the celeſtial matter to ſuſtain the ſun; and hence the influx of air to a common fire. This latter fluid is not viſible, but its current is perceived by its impulſe on the human frame and the apparent attraction of other bodies preſented before a fire. Therefore, altho' we ſee not the celeſtial matter flowing into the electrified bodies, yet as we are convinced that fire ſubſiſts in them, and that the ſolar pabulum is preſent in all places under the heavens, we muſt conclude that it flows into them. And the apparent attraction of light bodies ſurrounding them is an experimental proof of an influx of that pabulum to them, as real as that of air into fire. We ſee alſo, that in this electric, as well as in all other fires, the influx of its pabulum is proportioned to the quantity and conſuming power of the fire; for the prime conductor did not exhibit this apparent attraction, until it had taken in an addition of fiery matter: and further, when the accumulation of this fiery matter encreaſes, the exploſions and attraction grow ſtronger together. Therefore the diſtance, from whence this attraction takes place, ſhews the diſtance from whence the ambient pabulum flows to nouriſh the collected fires of the prime conductor. Conſequently the greater this diſtance, the more copious the influx, which is as the greatneſs of the exploſions, that is, as the quantity of fire accumulated in the conductor, which agrees with, and confirms the theory of the laſt ſection in the preceding lecture.

Now, if we conſider how ſmall the quantity of adventitious fire is which here cauſes attraction with regard to the ſtock of innate fires every body contains and affords, when kindled or in burning, we ſhould not be ſurprized at the centripetal ſpheres which ſurround all bodies, but on the contrary, ſhould wonder that ſuch ſpheres of influent matter are not larger. This proceeds from the innate fire's being dormant in moſt natural bodies, and conſequently its conſumption of fuel trivial. But tho' the concrete fires of body ſeem dormant and inactive, we have ſeen in the laſt lecture, that they cannot ſubſiſt without a nutriment diſtinct from the other concrete matters of the body; however the effects of this influent nutriment are generally inſenſible to our organs, until the fires are excited by friction, colliſion, heat, &c., juſt as the influx of the air to a weak fire is ſcarcely perceived, but becomes very ſenſible when it is ſtrengthened, or rouſed up with the poker.

This explanation of electric attraction is perfectly conformable to the cauſes of natural attraction we collected in the preceding lecture, and agrees both in cauſe and effect with the inſtance of the cupping glaſs. If then any man will not allow this to be a true and natural explanation of the phænomeaa, let him contradict it by ſhewing the lips, lungs and valves, or the hooks, fingers and muſcular powers the prime conductor has gained from the rubbing of the glaſs cylinder. Nor would an apparatus for ſucking or drawing be ſufficient without ſome power of rarifying or excluding the fluid imbibed and without a fluid thus to imbibe. Theſe we have in the laſt lecture diſcovered to be the apparatus and cauſes univerſally neceſſary for attraction, except where the conſumption of a fluid by fire produces that effect. Now we neither ſee nor can admit without abſurdity ſuch an acquiſition of machinery in the conductor; on the other hand we ſee the fire, and know its natural powers and effects: the concluſion is obvious and undeniable.

An electrometer is compoſed of a ſtick of glaſs, wax, or ſome other electric, from one of whoſe ends two ſmall balls of cork or pith of alder of about a quarter of an inch diameter, are ſuſpended by two linen threads, each five or ſix inches long. The electric cuts off the communication, which the electric matter would have from the balls to the hand of the operator, who being a living animal, is one of the beſt kind of conductors.

EXPERIMENT II.

ELECTRIFICATION in the prime conductor being excited as before, preſent the electrometer; its balls will be firſt attracted as in the laſt, and again repelled, and will then ſtand in receſs from each other, and from the conductor, until the electric matter they have imbibed is diſſipated in the air.

The exploſions as well in this experiment as in the foregoing prove, that fire was collected and compacted in the prime conductor; and conſequently it is there in a more denſe ſtate than it was in it before the attrition of the glaſs, or than it was in the light bodies carried to the conductor and adhering to it from the influx of the ambient fluid, as explained in the preceding experiment. Now this electric matter itſelf, being alſo a fluid, muſt, to form an equilibrium, flow from the prime conductor, where it is thus condenſed into the adhering bodies, where it is more rare, and continue thus to effuſe until all theſe inſulated bodies have it in the ſame degree of compaction and diffuſion, *i. e.* until its parts be in *equilibrio* through them all. But the eſſence and propenſity muſt *per* lect. 1. accumulate with the ſubſtance: conſequently the expanſion eſſential to fire muſt be acquired by thoſe bodies; and their expanſive emanations will encreaſe with the ſubſtance, which then oppoſing each other, muſt drive thoſe bodies aſunder, and alſo away from the prime conductor, which explains the repulſion of the balls of the electrometer and poſitive electricity in general, which ariſes, when bodies contain more than their natural ſhare of this matter, ſo as to effuſe it.

In the ſame manner the atmoſpheres of the planets and comets, being impregnated with the ſolar effuſions in Perihelion, will by a like counteraction of expanſive emanations diverge or recede from the ſun towards Aphelion, from whence they will return again by the motion of our celeſtial matter towards the ſun, as if by attraction, like the light bodies in the preceding experiment. Dr. Franklin agrees with us in this cauſe of repulſion, but then he is unacquainted with the true cauſe of attraction. As for Sir Iſaac Newton, we have ſeen that he enquired not into the cauſe of attraction or repulſion, and either conſidered them as effects of the ſame cauſe, or elſe treated both purely in a mathematical light, for he ſays (Q. 31) 'As 'in Algebra, where affirmative quantities vaniſh 'and ceaſe, there negative ones begin, ſo in 'mechanics where attraction ceaſes, there a re'pulſive virtue ought to ſucceed.' But here we ſee that repulſion commences in fact, when the bodies are ſaturated with the electric matter, which conquers the influent power or cauſe of apparent attraction, which phænomena muſt ceaſe and vaniſh, not when the bodies are at the greateſt, but at the ſmalleſt diſtance from each other. This is alſo evidently the caſe with the planets and comets in their acceſs and receſs, for where attraction ought to be greateſt in force next the ſun, a repulſion at once ariſes to overpower it without any correſpondence with the properties of Algebraic ſigns.

EXPERIMENT III.

Turn the wheel until the prime conductor is charged as before, which will be known by the aforeſaid phænomena, viz. the exploſions, attraction, and ſubſequent repulſion of the balls, which are all explained as before. Then let a perſon, or any piece of metal having communicion with the earth, touch and continue in contact with the conductor, all the ſigns of electricity will immediately ceaſe and remain dormant, while that contact continues, although the wheel be kept turning.

This ſhews that the electric matter goes off by theſe touching bodies, and that the matter of this kind is in the compoſition of ſuch bodies more rare than it is now in the prime conductor, where it is ſo accumulated as to produce exploſions. Theſe, and all other bodies by which it thus flows from the prime conductor, are alſo called *conductors.* And it is by this experiment that conducting ſubſtances are diſtinguiſhed from non conductors, which are diſcovered to be *electrics perſe.* Such are ſilk, glaſs, wax, and all ſorts of ſulphurous and reſinous bodies: for any of theſe being in contact with the prime conductor, though in communication with the earth, will not draw off nor ſuffer this matter to paſs thro' them from an electrified body; wherefore a charged conductor that touches this kind of bodies only, will be ſo inſulated as to exhibit all the ſigns of electricity as vigorouſly as if no body were in contact with it. But on the other hand, if a finger, or any conducting ſubſtance touch it, whether the electrics remain or not, repulſion, and all ſigns of electricity will ceaſe.

Quere, Is it becauſe glaſs, diamond, and ſuch hard tranſparent bodies are in ſubſtance a *continuum,* that they become impermeable to this matter? Yet by Experiment 1 they produce it: and the diamond of a ring worn, I think, by Sir Robert Boyle, had a ſpeck in it which frequently changed its place in that moſt hard ſubſtance. Theſe things argue a penetration of thoſe hard bodies; nay the laſt effect could only have been produced by the influent and effluent matters here ſpoken off. Is it from their texture alſo, together with the quantity of their native fires, that ſulphur, pitch, roſin, and ſuch inflammable bodies will not admit the entrance of any more? Yet ſilk, furs, hair, &c. are alſo *electrics per ſe*, and ſo is air tho' theſe bodies entirely differ from thoſe in texture. Again, glaſs and thoſe inflammable bodies become conductors when melted to a fluid ſtate; water is alſo a conductor, tho' it becomes an electric when congealed. Air too inſulates beſt in the time of froſt. Upon the whole then, cold is the only thing that as yet appears conſtantly and univerſally inimical and reſiſtive to the electric matter, agreeably to our obſervations in the 9th Lecture.

EXPERIMENT IV.

LET the prime conductor be again charged, and let a perſon ſtanding on a thick cake of roſin or ſulphur, or upon a ſtool with glaſs feet have communication with it by a metal chain, or any other conducting ſubſtance, and he will be alſo impregnated, ſo as to ſhew all ſigns of electricity as well as the prime conductor. Sparks will iſſue from his eyes, tongue, finger, or any other part of his body to which a conducting ſubſtance is preſented, which will cauſe a painful ſenſation, as if occaſioned by the touch of an hot wire point. Thus he will continue charged until he touch the ground with his foot, or communicate with ſome conducting ſubſtance in contact with the earth, and then all ſigns of electricity will ceaſe. By this experiment we ſee the natural propenſity wherewith this matter flows to the earth, and that its progreſs is ſtopped by electrics: all the other phænomena are intelligible from thoſe which have been already explained.

EXPERIMENT V.

NOW let a perſon ſtand upon a thin cake of wax or roſin, having communication with the prime conductor as before, electricity will not now riſe to ſo great a degree as when he ſtood on thick electrics, which ſhews that he is not ſo well inſulated as when he ſtood on them. This ſhews, that electrics are not always and in all circumſtances impermeable to this matter; for ſince the perſon and prime conductor thus inſulated do not afford ſuch ſtrong ſigns of electricity as in the laſt experiment, where all circumſtances were alike, except the thickneſs of the electrics on which he ſtands, it appears that ſome part of the electric matter, after a certain degree of accumulation, muſt have paſſed off thro' the thin electrics. Again, whatever kind of matter emanates from bodies muſt pervade their parts; but we know from experiment, that repulſive emanations proceed from glaſs, and other hard poliſhed bodies, which reflect light and prevent an actual contact of thoſe bodies without a preſſive weight: conſequently theſe bodies are not impermeable to the electric matter, which is the ſubſtance that emanates from them. Glaſs however may be impenetrable to a beam of ſolar light on account of the arguments adduced in the 7th lecture without any inconſiſtency; for a bank of earth or ſand, a body of twigs or furz will ſtop a current of air or water, tho' they be not impermeable to theſe fluids.

Indeed, notwithſtanding the accretions of air, light, &c. treated of in lecture IV. & VI, it muſt be owned, that the ſolar light, air and water are very much unqualified to enter any hard body without a preſſive cauſe; for attraction is but a name, and the two former fluids, at leaſt, are of a repulſive and diffuſive nature, and more adapted to ſpread over the ſurface of a body than to penetrate its parts, except from ſome compreſſion and concentration, as if to a focus. But our celeſtial matter being of convergent propenſity, is of a penetrative nature, and is preſent in all places, whence it flows to the ſun and to the concrete fires of every body, as if to a focus, which it nouriſhes and preſerves, thereby preventing the waſte and conſumption of the body's ſtamina. This matter therefore is the principle of convergence, and the ſole one; for by ſect 4. lect. 1. the ſimplicity of nature will admit but one. It is therefore the cauſe of the entrance of air, light, water, &c. into bodies; and as it carries in theſe matters in its influx, we ſhall in this view call them with it influent matters. Whence again we have room to conclude that this matter is the cauſe of the phænomena of all attractions.

In this experiment we ſee that even electrics are yielding to electrical emanations, and muſt therefore be permeable to the ſame kind of matter, eſpecially when they are thin. For the ſame reaſon we ſee that this matter finds a paſſage thro' air, tho' an electric, to a needle point, held at a ſmall diſtance from the prime conductor. For this being alike inſulated on all ſides by equal columns of air which reſiſt the protruding emanations of electric matter acting equally on all ſides, and cauſing equal vibrations in the ambient air, retains its charge; but where the point is preſented, it is leſs ſuſtained on that ſide, the ſtratum of air being thin; the vibrations therefore are there broken, and the emanating matter preſſes on the yielding part of the air, and thus forms a ſtream to the conducting point, whereby it eſcapes into a body, where its ſubſtance is more rare. In like manner it forces a paſſage thro' ſharp corners or prominent points of the prime conductor, where it is ſo accumulated, and iſſues forth in a ſtream which turns a wheel and ſhines in the dark. A prime conductor then of a ſpherical form, with ſuch points and prominent parts when ſaturated with this matter, would in a dark room, give a miniature appearance of the earth and its vulcanoes; may not then the cauſes, as well as the phænomena be ſimilar in both?

The different degrees of electrification, which the ſame conductor and apparatus admit of in the ſame place, but in different kinds of weather, ſhew that the electric ſtate and quality of the air is very changeable. For during froſt or dry cold weather, the electricity *ceteris paribus* will be ſtrong and lively, which ſhews that much matter is then accumulated and condenſed in the prime conductor. In moiſt or rainy weather there are ſcarcely any ſigns of it, except in a warm room, where it may be raiſed to the degree ſuch an atmoſphere will admit of. Humidity in this caſe ſeems to damp the electric matter as it would gun powder; or it may be that in this ſtate the ambient air is a non-electric. But even in the coldeſt weather, after a certain accumulation of this matter in the prime conductor, electricity cannot be increaſed without an additional apparatus; for any further acceſſion of this matter will then force its way into the atmoſphere. Whence we ſee that the preſſure of the air is not the cauſe of its confinement in the conductor, the weight of the atmoſphere being often the ſame in both kinds of weather, as appears by the barometer.

EXPERIMENT VI.

NOW let the whole apparatus and the man who turns the wheel be entirely inſulated, by placing them on thick electrics, or ſuſpending them with ſilken lines, ſo that all communication between them and the earth be cut off. The prime conductor may at firſt give ſigns of electricity, but after a time they will ceaſe, and will not return while the machine and operator are thus inſulated, altho' he continues turning the wheel; unleſs he puts his foot to the ground, or touches another perſon, or ſome conducting body communicating with the earth. But the inſtant this happens, all ſigns of electricity will be renewed and exhibited as in the 1ſt and 2d experiments. This ſhews, that the electric matter flows from the earth, and is collected, not produced by the apparatus as electricians firſt imagined, before Doctor Watſon made this diſcovery. However it muſt be allowed from the firſt temporary ſigns of electricity which appeared while the machine was inſulated, that ſome electric matter was collected from the air, machine, and operator, which ſoon diſcontinued to flow. And it is obſervable, that the more perſons or bodies of any kind are thus inſulated together, the ſtronger and more durable are theſe firſt ſigns of electricity; which ſhews, that all ſuch bodies contain this matter in proportion to their magnitude. Conſequently the quantity of this matter in all bodies on the ſurface of the earth, is but a trifle with reſpect to what the earth itſelf contains; and this is again clear from the futility of the firſt ſigns of electricity while the machine was inſulated. Therefore, (*per* lem. 3.) the influx of the celeſtial matter into this planet muſt be immenſe. May not then the centripetal ſphere, formed by this influx, be the cauſe of terreſtrial gravitation?

But to return to our experiment: from the ceſſation of electricity by inſulating the machine, &c. and from its conſtant flow, while theſe bodies communicate with the earth, it is evident that there is a continual circulation of electric matter from the earth by conductors to the rubber and glaſs globe, and thence to the prime conductor, and *per* 4th experiment, back again by other conductors to the earth: the manner and reaſon of which we ſhall now examine. In the 5th lect. we have ſeen that the elaſtic matter of the hardeſt bodies is rouſed from its dormant ſtate by colliſion or friction, which excites a tremour in its parts and gives it motion; and that its own expanſive eſſence thus rouſed to exertion, makes it come forth, ſo as to excite heat in the fricted bodies, and ſometimes kindle them. In like manner the looſe matter of this kind in the rubber and glaſs is rouſed and ſet in motion by the tremour of their parts, and urged by its excited expanſion to the rubbing ſurfaces, where a rarifaction of this matter firſt takes place by a diſcharge of a part at the commencement of action. The adjacent parts then, having gained liberty, muſt flow thither, as it were to reſtore the equilibrium; the parts beyond them from the ſame cauſe muſt follow them, and thus a motion of that kind of fluid muſt be propagated thro' all touching bodies to the earth, whoſe looſe matter of this ſpecies muſt flow in the ſame direction to the rubbing ſurfaces, where a rarifaction of this fluid has been produced and is maintained by the friction. Thus the electric matter is ſollicited to come from the earth to the rubbing ſurfaces on the ſame principle that actuates air to flow to the fire, and alſo from another cauſe, *to wit*, the powerful conatus which every fluid acquires in flowing towards the place of its tendency. Arriving here then it continues lambent on the glaſs, until ſome conducting body or point preſents itſelf within the extent of its emanating ſphere, which being preſented it paſſes by it into the prime conductor, which being inſulated, its motion is there ſtopped; and conſequently it will be there collected and accumulated, as water collects in a pond at the end of its ſtream: and as in this caſe no more water will be collected than what the banks can hem in, ſo no more electric matter will remain in the conductor than the air in its preſent ſtate is qualified to confine. But while the prime conductor is thus filled to ſaturation, it will by its emanations cauſe repulſion or poſitive electricity, whereas the operator and the other parts of the machine, where this matter is not thus dammed up to a redundancy, but only in paſſage flowing to the prime conductor, will effuſe none, and therefore will not be poſitively electrified; but they will exhibit negative electricity by the attraction and adheſion of light bodies; becauſe the celeſtial matter will flow into them to nouriſh the electric fire in paſſage thro' them: ſo that we find the ſame matter produces poſitive or negative electricity, as it is differently circumſtanced. The more cold the air, the more this matter will be condenſed in the prime conductor, and the converſe. But moiſture is a vaſt obſtruction to the accumulation or retention of this matter, for every kind of liquid ſubſtance is a conductor, even an electric *per ſe* becomes ſo when reduced to a liquid ſtate; the natural reaſon of which, and of the difference between electrics and non electrics ſeems to be as follows:

The electric fluid is a looſe kind of the elaſtic matter not yet contextured in the ſtamina and firm parts of bodies; for which reaſon it is eaſily diſengaged and ſet in motion. Hence it is that an eaſy tremour excited by a ſoft rubber gives it motion and continues its propenſity from every part of the body to the fricted ſurface. Porous ſpringy bodies therefore and fluid ones eaſily yield this matter, for the ſpringy fibres of the firſt will eaſily diſlodge and remove it, and in the fluid it is ſcarcely tied town, ſo that a ſtream of it is eaſily formed through theſe two kinds or thro' other bodies approaching the texture of either. But where the texture is cloſe, firm, and tenacious, a paſſage is not eaſily gained, nor do ſuch bodies contain much of this looſe kind of matter, being chiefly compoſed of, and impregnated with an adheſive kind, which is not eaſily diſlodged or removed. And even tho' friction and tremour may looſen and diſcharge ſome of this matter from ſuch bodies; unleſs they be very thin, it requires more time than is generally taken to make an experiment in order to liberate and give motion to what they contain, that more extraneous fluid of the ſame ſpecies collected from other bodies may paſs thro' them, ſo as to give it a paſſage to and from the earth. Conſequently the more nearly bodies approach to this kind of texture the nearer they are to the nature of electrics.

That the earth is the grand fountain and ſtore of the electric fluid, from whence electricity is ſo abundantly ſupplied on all ſides and parts, is evident from theſe reaſons, 1ſt, it appears from this experiment, that all bodies contain this fluid in the proportion of their quantities of matter. 2dly, The fires of bodies in a general way may be alſo conſidered as proportioned to their quantities of matter; and the electric fluid, according to the œconomy of nature ſeems to be the firſt ſolution ariſing from the elaboration of the influent matters made in the pores of body, where it remains as it were the digeſted nutriment deſtined for the preſervation of theſe innate fires centextured in the firm ſtamina. It muſt therefore be abundant in an extraordinary degree in the earth, which is ſo immenſely large in reſpect to the bodies on its ſurface, and which from its heat vulcanoes and power of vegetation we have concluded to be replete with fire. It is not ſtrange then that all electric operations ſhould derive vigour and efficacy from a communication with the earth. But the part of the experiment that remains to be explained is, why the electric matter, when ſo abundant in the earth, ſhould yet return into it, not only by conductors, but alſo by thin electrics. This proceeds from two cauſes, firſt this matter is more ſubject to the gravitating fluid than any other kind of fire or light, as appears from its immediate deſcent in a perpendicular cloſe column, in an exhauſted receiver, while other kinds of light are only refracted, and that at the ſurface of bodies by the influence of this celeſtial or gravitating matter. 2dly, We have ſeen that it recedes from cold, and of all neighbouring bodies the atmoſphere is the coldeſt, from which therefore it muſt run to the earth, and to all bodies which afford it a paſſage, and wherein it may be ſcreened from this condenſing cold.

EXPERIMENT VII.

INVERT the order of the apparatus, let the perſon who turns the wheel be inſulated, and a chain be hung from the prime conductor to the earth, ſo that the wheel being turned the matter muſt flow from the earth, not thro' him as before to the prime conductor, but thro' the chain and prime conductor to him. Inſtead of being the channel as he was in the former experiment, he now becomes the pond into which this matter flows, and where it is damned up. Hence the effects are changed; for the exploſions and emanations now proceed from him, not from the prime conductor, ſo that he is electrified poſitively and the machine negatively, the matter being accumulated to ſaturation in him, and only in paſſage thro' the machine. Whence again we ſee the circumſtance, upon which poſitive and negative electricity depend. But let the inſulated operator now lay his foot on the ground, or gain communication with the earth by any conducting ſubſtance, all the electric matter will immediately flow through him to the earth, and loſing his redundancy of this matter, he will loſe his poſitive electricity as in the 4th experiment.

EXPERIMENT VIII.

LET a ſingle cork or pith ball ſuſpended by a ſilk thread be electrified by touching the prime conductor, and then carried to the middle of the room, where the air is alike qualified on all ſides. Here it will be at all parts under an equal preſſure of the air, againſt which the emanations of the ball or its repulſive atmoſphere will act equally on all ſides. Conſequently it is here kept at reſt as water in a ſtaunch veſſel. But a conducting ſubſtance being preſented at the bounds of its atmoſphere, attraction (to ſpeak in the received manner and according to ſenſe) will enſue; for the electrified body will approach and ſtick to this conductor. But in reality it might as well be ſaid that a gimblet hole in the ſide of a veſſel attracts the water to it; for juſt as that perforation deſtroys the reſiſtence that had preſerved the equilibrium of the water, ſo the conducting ſubſtance thus preſented deſtroys on one ſide the equilibrium that ſubſiſted between the action of the electric or repulſive fluid and the reſiſtence or preſſure of the influent matters, by abſorbing the electric fluid on that ſide.

Mean time the action and reſiſtence remaining in force on the oppoſite ſide preſs the light body againſt the conducting ſubſtance, unto which it adheres until all the emanating matter is abſorbed or diſſipated: then the action ceaſes on all ſides and the light body falls off. If then it be brought near to the prime conductor or any electrified body, it will exhibit another apparent attraction thereto, which ariſes from the motion of the celeſtial matter preſſing into the electric fire of the impregnated conductor, and forming around it a centripetal ſphere of celeſtial matter, whoſe influence in theſe and all other electric experiments is the principle of attraction and approach, as we have ſeen in the firſt experiment.

EXPERIMENT IX.

When the prime conductor is charged, approach it with a little cork ball, a downy feather, or thiſtle down, ſuſpended by a fine ſilk thread, which being ſaturated, will be repelled as in 2d experiment. If, while in receſs, this light body be touched by a finger or wire point, it will be exhauſted as *per* 3d and 8th experiments, and the ball or feather having depoſited its charge in the conducting ſubſtance, will from the preſſure of the influent matter be drive to the prime conductor for another; and having been again impregnated, will from the repulſion before explained, return to the finger, and then go back as before. Thus it will continue going backward and forward between both, depoſiting with one the matter it receives from the other; the reaſon of all which is evident from the 1ſt, 2d, 3d, and 8th experiments.

Again, inſtead of a conducting ſubſtance, let an electric of the reſinous or ſulphurous kind be excited and put in place of the finger or wire, and the effect will be the ſame; the ball will move between it, and the prime conductor as in the preceding caſe. Now ſince all phænomena are here the ſame, the principle of action muſt be the ſame. But in the foregoing caſe the finger and wire being conducting ſubſtances, abſorbed the emanating matter, which the light body had received from the prime conductor. Shall we not infer the ſame of the reſinous body in the ſecond caſe? For altho' this body be an electric, it is not in a ſtate of ſaturation, and may abſorb the emanaſions produced by vitrious electrics. If ſo, the phænomena of this experiment correſpond with, and illuſtrate the perpetual motion of a comet between the ſun and firmament, whoſe effuſions mutually abſorb each other, each ſpecies of matter being ſuſtained and repleniſhed by what it receives and aſſimilates from the oppoſite fund. From a correſpondence of effects we might deduce a correſpondence of cauſes, and conclude, that the reſinous or ſulphurous body abſorbed the vitrious electric matter, which the light body carried to it from the prime conductor. But this we muſt examinemore deeply. In our 6th and 7th lectures we collected that glaſs is a continuous body ſtrongly impregnated with fire, which is ſhackled down in its conſtitution in an adheſive conſolidated form by the coercive principle: from its ſtrong impregnation with the elaſtic matter, and its firm continuous texture, it derives a power of tremour which vellicates the electric matter of contiguous and remoter bodies, from whence this fluid gains motion to the fricted ſurfaces, and thence to the prime conductor, as explained in the 5th experiment; but not having pores to neſtle and concoct the influent matters into electric matter, it is not ſo productive of this matter as other bodies, but is well qualified to rouze it and to excite its motion from them: whence it is that glaſs is always electrified *plus* on the ſide whereon this matter flows, tho' frequently *minus* on the other, when it does not partake of the lambent matter; for the influent matter, preſſing thro' it to the fires of the poſitive ſide, brings bodies to, and makes them ſtick to the negative ſide, where they may remain a long time before they receive as much as will cauſe repulſion, except it flows from other bodies. On the other hand, ſulphurs, reſins, and ſuch opake bodies, being porous and of a fiery nature, are more elaborative of influent matters, and conſequently more generative and productive of the electric matter than what glaſs is; yet not ſo collective of it from other bodies. The fertility of ſuch bodies in this kind of matter may be judged of from their odorific power, which alſo increaſes when their fires are ſtimulated by friction. But ſince they do not collect from other bodies as much as they generate of this matter, they are with regard to the received qualities of electricity, more of the negative than of the poſitive kind; becauſe, in ſuch circumſtances, the quality of the influent matters which they abſorb, is, without any loſs of matter in the elaboration, greater than the repulſive or electrical kind they produce; for the influent matters are compoſed of the celeſtial and the other fluids, which it carries with it into bodies, ſuch as air, light, &c.; whereas the repulſive cannot be more than is its conſonant ſubſtance, *i. e.* light or fire. Now, if in a curſory way we would judge of the proportion between the influent matter of the body and the electric matter it produces, let us conſider the proportion of their fountains, *i. e.* the concave ſurface of the heavens and the convex of the ſun, for theſe are the ſources of the ifluent matters, to which the quantity of each kind entering into the bodies muſt be proportional. Or otherwiſe, let us decide by the quantity of theſe elements concreted in body; now the electrical can be only as the quantity of fires in that body, with regard to the other matters, firſt, becauſe it elaborates in that proportion; and ſecondly, the repulſive power cannot be more than its adequate ſubſtance. Whence the electrical or influent matter of body, diſtinguiſhed by repulſion, ſhould be very ſmall in reſpect to the influent; but the influent matter is the cauſe of preſſure on body, which gives the appearance of attraction, and the expanſive emanations are the cauſe of repulſion. Conſequently thoſe bodies which are more generative of this matter than collective of it by tremour, ſhould be more attractive than repulſive. And becauſe the celeſtial influent is predominant and abſorbent of the expanſive fluid, the electrical matter of glaſs may be abſorbed by a reſinous or ſulphurous electric as well as by a non-electric, (which explains the phænomenon of this experiment) until a balance is formed; and then, as in every caſe where the electric matter abounds ſo much in quantity as to ſaturate other bodies, a repulſive power will enſue, as remarked in the 2d experiment. This abſorption ſhall be more fully explained in the next experiment with which we ſhall conclude, for it is unneceſſary to run into a detail of others, whoſe ſolution is clear from the principles already eſtabliſhed.

EXPERIMENT X.

IS an extract from papers preſented to the Royal Society in 1759, by Mr. Symmer, containing ſingular phænomena, which have not been ſolved by any theory hitherto invented, but which ſtrongly illuſtrate and corroborate ours. This gentleman having been accuſtomed to wear two pair of ſilk ſtockings together, *to wit*, one black and the other white, remarked, that in pulling them off he heard a crackling, and in the dark perceived ſparks of fire between them, which phænomena gave him the idea of their being electrified. He afterwards found, that to electrify them at any time, the ſtockings being on, it was only neceſſary to rub his hand ſeveral times over his leg, then the ſtockings being drawn off, ſeparated, and held at a proper diſtance from each other, appeared highly electrified; the white poſitively, and the black negatively, while they were thus kept ſeparated, both were ſo inflated as to ſhew the full ſhape of the leg. But when a black and white ſtocking were preſented to each other, they were mutually attracted, and would, if permitted, ruſh together with violence; as they approached, the inflation gradually ſubſided, and their attraction of foreign objects diminiſhed; but their attraction of each other increaſed. When they actually met they became flat, and joined cloſe together like ſo many folds of ſilk, and when ſeparated again, the electric virtue did not ſeem to be in the leaſt impaired. When the experiment was made with two black ſtockings in one hand, and two white ones in the other, being preſented together, they were thrown into ſtrange agitations owing to the attraction between thoſe of different colours, and the repulſion of thoſe of the ſame, which mixture of attraction and repulſion made the ſtockings catch at each other at greater diſtances than they would have done. When two black or two white were held in one hand, they would repel each other forcibly, ſo as to make an angle of about 30°. (Whence we ſee thoſe of a negative quality repelled each other as well as thoſe of the poſitive). But when two of different colours were preſented together, they attracted each other ſo powerfully, that at one time they required 10 or 12 ounces, at another time 17, *i. e.* more than the weight of the ſtockings in order to ſeparate them. Having got the black ſtockings newly dyed, and the white ones waſhed and whitened in the fumes of ſulphur, and put them one within the other with the rough ſides together, it required three pounds three ounces to ſeparate them, the attraction being always ſtronger as the ſtockings were more ſubſtantial. When the white ſtocking was put within the black, and the outſide of it contiguous to the inſide of the black they raiſed 9℔, and when the rough ſurfaces were contiguous they raiſed 15lb, &c. From theſe great powers of electrical attraction, it is natural to conclude, that as the agents of nature are as few as poſſible, whatever be the cauſe of theſe effects, is alſo the cauſe of the coheſion and firmneſs of natural bodies.

Now to interpret all parts of theſe experiments, according to the concluſions clearly educed in the preceding ones, it is evident that the ſtockings being rubbed on the leg, were ſaturated by the electric matter immediately iſſuing therefrom, which was replaced by the ſame kind of matter coming from the earth. 2dly, It is clear from experiment 2, that their inflation when ſeparated aroſe from the emanations of this expanſive matter, which was compacted in them along their interiour ſurfaces, the repulſion of that within ſwelling them as if they were blown up with air, and the emanations of that without cauſing the phænomena of repulſion, and alſo the attraction of light bodies, as explained in the preceding experiments. But why the electricity of the ſame coloured ſtockings ſhould be repulſive or poſitive with regard to themſelves, and at the ſame time that of oppoſite coloured ſtockings attractive, the black being negative, and the white poſitive, are more extraordinary inſtances of electricity than any that have yet occured. For in all theſe ſtockings the ſubſtance and texture is the ſame, whereas vitrious and reſinous ſubſtances differ not only in colour, but in ſubſtance and texture. We muſt therefore conclude, that the colours only, or the matters which ſuperinduced theſe colours on ſilk, are the cauſes of theſe different powers. And this is alſo clear from the increaſe of the effect when the colours were ſtrengthened or renewed: but this requires further inveſtigation.

A ſolar beam let into a darkened room, will make the ſpot on which it falls appear white. Refract this beam by a triangular priſm of glaſs, the white ſpot will vaniſh, and a long variegated ſpectrum will ariſe of ſeven ſtrong and beautiful colours. Then if all theſe different coloured lights are again convened by a convex lens, the ſpectrum will vaniſh and be changed into a white ſpot again. As theſe priſmatic colours are ſpontaneouſly and immediately formed from the ſolar beam by a ſingle refraction, they are ſaid to be original colours; but as, when together in the beam before or after refraction, they produce a white ſpot, philoſophers agree, that white is an equal mixture and reflection of all thoſe colours. They alſo agree that the natural colour of any body ariſes from a power or diſpoſition in it to reflect that kind of original light, of whoſe colour the body is, the reſt being abſorbed by it. Black they conſider as an abſorption of all colours; for, if the body reflected all the primary colours, it would be white, if it reflected one or more of them, it would be of that colour, or of a ſhade between thoſe it reflected; therefore, reflecting none, it muſt abſorb all. Experiment ſeems to confirm this; for let a black and a white body of the ſame kind, ſuppoſe two tyles be alike poſited before the ſun, the black one will be hot before the white is warm, which ſhews, that the black body received the matter of light into its ſubſtance, and the white body threw it off by reflection; for heat and light are here concomitants.

But we have ſeen in the 9th Lecture, that our celeſtial matter is not only the ſolar and ſidereal pabulum, but alſo an abſorbent of light, as well in bodies as in the celeſtial ſpaces. We had before, Lect. IV. & VI, analyzed three

three elementary matters, *to wit*, the inert matter which is void of all powers, the gravitating matter which is the principle of weight and coheſion, and light which is the principle of expanſion, &c. Theſe elementary matters we have ſeen, Lect. IV. & VII, are concretes in all bodies, contextured in various proportions to be judged of by the predominant qualities of each body. The celeſtial matter then, which is the abſorbent of light, muſt in black bodies be in the greateſt proportion, while white bodies have ſo ſmall a ſhare of it with reſpect to their luminous concrete, that they do not abſorb, but reflect light. Again we have proved, Lect. V, that the elaſtic and electric matter are the ſame principle, and this principle we inveſtigated, Lect. VI, to be compoſed of two matters, then denominated the expanſive and the coercive, but which in reality are the ſolar and celeſtial matters, the latter of which had not then been exhibited. The electric fluid then, being compoſed of theſe matters, is allied to theſe predominant principles in black and white bodies, or in thoſe of any other colour. Again we have ſeen in the IVth & VIIth Lectures, that the elementary matters, and other fluids, which enter into the compoſition of body, are aſſimilated to its nature and partake of its qualities, the reaſon of which appears in lem. 2. lect. 11. Therefore the electric matter of the white ſilk ſtockings, muſt be more repulſive than that of the black, each effluent ſubſtance being of the ſame nature with the matter or concrete predominant in the ſtockings, from which it emanates. Conſequently the quality of the black ought to be negative, when that of white is poſitive, for in this the ſolar is in the higheſt proportion, and in that the celeſtial matter prevails.

Again, theſe matters are nutrimental, and therefore abſorbent of each other. Conſequently the emanations of electric matter from the black and white ſtockings muſt, like the the principles of thoſe colours, be mutually abſorbent and nutrimental to each other. And therefore when the black and the white ſtockings are preſented to each other, the emanations of their electric ſpheres being like their principles abſorbent of each other, deſtroy action and reaction in the intermediate ſpace between them by a mutual abſorption, while their emanations remaining unimpaired on the outſide act againſt the influent matters, which react againſt the ſtockings, ſo as to preſs them together with the force remarked in the experiment, wherewith they fold together, bear weight, and exhibit all the phænomena of apparent attraction; this may give ſome inſight into the cauſe of coheſion in bodies, which is encreaſed by cold, a quality of our celeſtial matter. But on the other hand, when two ſtockings of the ſame colour are preſented together, their emanations, being of the ſame quality and therefore not abſorbent of each other, retain their expanſive vigour, and like the ſaturated balls of the electrometer, are repulſive of each other, diverge and ſtand in receſs, until exhauſted of the expanſive matter, which is the cauſe of all the repulſive phænomena in thoſe experiments.

SECTION II.

Electrical Theory extended. Cauſes of the Motion of the Moon and other ſecondary Planets. Her Perturbations, the Preceſſion of the Equinoxes, and Phænomena of Tides ſolved by our material Principles.

IN the ſtrange agitations and vibrations of the different coloured ſtockings when preſented together, we perceive the cauſe of the perturbation of liquors in the ſtate of fomentation and chryſtalization, which ſome experimentaliſts pretend to explain by *attractions* and *vortical motions* of the particles of matter. How particles of inert matter ſhould have theſe vortical motions without ſome additional cauſe to give them a rotary motion, is hard to explain. And ſuch theoriſts bring all the complications of the cartheſian vortices into every fermenting fluid. But the truth ſeems to be, that a fermenting liquor, like an electrified body, is impregnated and charged with its lively fires in the form of a freſh volatile ſpirit, not ſufficiently ſaturated or ſhackled down by the celeſtial matter, which, as to a prime conductor, flows to it more forcibly than it does to other bodies whoſe fires are ſettled and dormant, and in its influx it bears down ſmoak and flame to reſtore the equilibrium thoſe fires deſtroy. Whence it is ſaid the exhalations of ſuch liquors are heavier than atmoſpheric air.

The digeſtive power peculiar to fire, and the conſumption of its pabulum, are here the mean ſpring of action. A liquid blown up by its expanſion, broken by the incidence, and born down by the preſſure of the celeſtial matter the pabulum of its innate fires is the ſole cauſe of thoſe vortical motions, without any other apparatus or complication of principles, except the emanations of the ſun and firmament, which in their paſſage to the earth blend with the air, and are influent into all bodies; and are here as well as every where elſe, the great material agents of all the operations of nature. From theſe principles then an elaboration will continue until the fires are ſaturated and ſhackled down by this matter, and both contextured and tempered to the nature of the liquor to be produced. In this fermenting liquor the nutrimental parts are retained, as is the caſe with air inſpired by animals; and as in that caſe alſo the groſs, impoveriſhed parts are excluded by the operation of the liquor, like the expirations of animals, or like the famiſhed air that has paſſed thro' fire. Such emanations therefore are more noxious than nutricious to animals, to flame, or to vegetables, all which therein expire for want of this nutrimental part in their inſpiral matter. Even a ſolar beam conſumes this nutrimental part of the air; wherefore, if a beam be incident on a fire, the latter will dwindle and die away for want of nutriment, ſo that to preſerve the vigour of the fire, it muſt be ſcreened from the ſun ſhine. Whence it is plain, that the celeſtial matter is the nutrimental part of the air, or that it blends with that fluid and gives it the quality of feeding fire. For when this matter and its qualities predominate, as at night, or during froſty weather, then fires are well ſuſtained by the influx of air, and burn briſkly; but when this matter is abſorbed and devoured by the ſun beam, which as well as the ſun is conſumptive of the celeſtial matter, the air thus impoveriſhed is incapable of giving vigour to flame, and unqualified for other purpoſes of nature. Hence the danger of inſpiring the recent effuſions of odoriferous, or copiouſly effuſing bodies; where there is not a free circulation of air to recruit theſe exhauſted expirations. Hence ſuffication from the fumes of charcoal, &c.; hence gaol diſtempers, the cataſtrophe of Calcutta, and numberleſs calamities proceeding from the inſpiration of impoveriſhed air, which cannot be ſalubriated without impregnations of the celeſtial and ſolar matters in open circulation, where both are blended together.

From the unceaſing effuſions of bodies of the animal, vegetable, and fluid kind which affect the ſenſes, and of which we have ſpoken largely in the courſe of this work: from the inviſible emanations of foſſils, which are found to be ſo copious and conſtant, that the very hardeſt of bodies, ſuch as poliſhed ſteel, glaſs, &c. cannot be brought into actual contact without a conſiderable weight and preſſion: in fine, from the prodigious evaporation of the waters of the earth, the exhalations of her own body, and all the bodies ſhe contains, three inquiries naturally ariſe, which may lead to important diſcoveries. The firſt is, what ſupplies the loſs which the earth ſuffers by ſuch effuſions of ſubſtance? For the immediate inſpiration of her own expired matter, to judge from univerſal analogy and reaſon itſelf, ſhould reduce her vigour, ſpirits and magnitude, and induce the decay of her productions. But ſhe and all her bodies comparatively, are now in vigour and powers, what they were an hundred or a thouſand years ago; ſee our 1ſt lect.

The anſwer is obvious: the ſolar and celeſtial matters ſupply theſe loſſes. The earth therefore and her bodies form another mart of traffic, their fires and digeſtive powers being the mean ſpring of action, as well as the cauſe of vegetation and pneumatic generations. For the earth and her bodies, with their concrete fires, are the furnaces, retorts, and digeſters of nature, wherein thoſe influent matters are both the fuel and ſubject of elaboration. Their ſolutions are the reſulting juices, ſpirits and ſalts, with the reſpective qualities and virtues peculiar to each body to which theſe nutrimental ſubſtances were aſſimilated, according to the divine mandate of the Creator, which in all caſes is the governing principle in nature. Hence then a perfect union and transformation of thoſe ſubſtances into that of the body, to preſerve its qualities, texture, and elaſticity. And hence again, theſe factitious airs lately diſcovered, with the expirations that ſtand round each body. For theſe effuſing matters are excluded after elaboration, by the repulſive action of their own elaſtic baſis, as before ſignified, lect. 3. and the ſucceſſive preſſion of the influent matters, which is ſuſtained and enforced by the centripetal ſphere the celeſtial matter forms round every body. The firſt ſolution of theſe matters ſeems to be the electric matter in bodies, ſurrounding their ſtamina in a ſtate of aptitude to nouriſh their contextured fires. And the excluded repulſive matters reſulting from the elaborations aſcend into the atmoſphere, whence a ſecond queſtion.

2dly, From ſuch ſupply and digeſtive power in the earth and its bodies, ſhould not the atmoſphere be prodigiouſly encreaſed? For ſuch production of the emanent matters that compoſe the atmoſphere, muſt be in proportion to the magnitude of the earth and its bodies, with the quantity and vigour of their fires. An electrified conductor will have a repulſive ſphere of emanation, whoſe depth is greater than its own radius. This may be known from the diſtance between the ſaturated balls of an electrometer, whoſe repulſive ſpheres are formed in an inſtant. Now that the earth, whoſe radius is near 4000 miles, and which is ſo replete with vigorous fires, as appears from its vegetative powers, vulcanoes and earthquakes, ſhould every inſtant produce one of 50 miles high, does not require a repulſive power nearly adequate to that of the balls or other electrified bodies, ſo that in a day, at leaſt in a year, I will not ſay a century or ten, our atmoſphere ſhould ſwell to many thouſand miles high. But the lengths of twilight are found every year the ſame, at the ſame place, and with the ſame declinations of the ſun. Conſequently the atmoſphere continues the ſame in height and magnitude. It muſt then tranſmit to the celeſtial ſpaces the redundancy it thus receives continually from the earth and its bodies. The atmoſphere therefore is the medium of a reciprocal commerce between the heavens and the earth. Hence it is that the Earth and its bodies retain their ſtated magnitude and vigour: hence the matter of the univerſe is the ſame now as at the creation: hence the truth of our ſecond axiom, lect. 1. with its illuſtrations and conſequences relating to the perfection of the univerſe and ſufficiency of its principles, founded on the wiſdom of the Creator: and hence, infine, the Divine Oeconomy uſed in the formation of the world; for tho' Omnipotence could have formed or renewed at each inſtant the works of the Creation, yet the ſame divine frugality that formed the retina of the eye without any ſuperfluous extent, and ordered the fragments of the bread and fiſh to be gathered, that nothing ſhould be loſt, hath alſo diſplayed itſelf in the creation of the univerſe, and, by a bounding ſhell and ſuſtaining intercourſe between all its parts, hath prevented the waſte and vain effuſion of matter thro' infinite ſpace, and provided for the permanency of his works by a mutual intercourſe and traffic of matter within bounded ſpace, where corruptions are the ſources of generations, the effuſions and waſte of one kind of body being the aliment and ſupport of another. The effuſions of the ſun and firmament are then to each other a reciprocal nutriment; and both join to nouriſh the planets with the earth and its bodies, all which are rendered vigorous and fruitful, by a conſumption and elaboration of theſe two influent matters to the form of our elaſtic matter. This matter being aſſimilated to the proper nature of each body, they effuſe it in the form of air, of animal, and vegetable exhalations, &c. to refund to the celeſtial bodies a return for their ſupplies, of which traffic the atmoſphere is the medium.

3dly, If we compare the ſpheres of the influent matter that ſurround the celeſtial bodies with the extent of their repulſive emanations; if we compare the quantity of fuel conſumed by a common fire with the quantity of flame it emits, or the extenſive current of air flowing into it with the ſmall diſtance to which its repulſive power (if it has any ſenſible one) extends, muſt we not conclude, that to produce ſuch quantities of atmoſpheric air, the earth muſt have an immenſe conſumption of celeſtial matter, ſo that its centripetal ſphere of this influent matter muſt be of very great extent, and conſequently higher than the moon? But without thoſe conſiderations, we ſhould draw that concluſion from the perpetual revolutions of that ſatellite about the earth; for we have ſeen, that attraction, without an influent ſubſtance, is either a mere abſtract idea or an inconſiſtent notion repugnant to reaſon and experience. Conſequently, the moon is kept within her orbit by the centripetal ſphere of our celeſtial matter, which preſſes her towards the earth, and acts now with reſpect to the earth, as we have before explained of the primary planets with regard to the ſun. On the other hand, the flood of repulſive matter aſcending from our atmoſphere into the heavenly ſpaces, acting on her repulſive atmoſphere, will cauſe her receſs from Perigeon to Appogeon, and the ſame of the other ſecundary planets. And thus we have material cauſes for the periodic motions of the ſecondary planets of the ſame powers, propenſities, and proportionable efficacy with thoſe which produce the periodic motions of the primary planets; which ſimplicity, and familiarity of cauſes and modes of action are the great object and principal ſupport of any phyſical ſyſtem.

It is ſaid, indeed, that the moon has no atmoſphere, becauſe there is no refraction of ſtar-light at her margin, nor floating clouds perceived on her diſk; and this might be thought an objection. But from Newton's rules, her matter muſt be ſuppoſed like that of the earth, or ſome of its foſſils, all which have their innate fires. And we have no conception of any other kind of opaque or tranſparent bodies than thoſe we know. Now the moon being ſo much expoſed to the ſolar and celeſtial fluids, ſhe muſt alſo have her concrete fires: and theſe muſt be nouriſhed and ſupported by our influent matters, to preſerve her texture, and prevent the ruin which would ariſe from the devouring nature of her concrete fires. And this influent matter muſt be the celeſtial effuſions that being the fluid which ſurrounds her, is conveniently placed, and is by nature nutritive to all ſorts of fire. Therefore it muſt form about her a centripetal ſphere, whoſe quantity and dimenſions are proportionable to her magnitude and fires. Theſe fires, like all others, have their digeſtive and tranſforming powers; wherefore ſhe elaborates the ſolar and celeſtial matters to refine and effuſe them again. Conſequently the ſolution of theſe two elementary matters of oppoſite eſſence, muſt be a fluid endowed with both eſſences in the form of air, with its elaſtic baſis and buoyant power fitted for tremour, all which conſtitute it an atmoſphere like ours, and a medium of commerce thro' which her repulſive emanations aſcend to the celeſtial regions to repay the nouriſhment ſhe thence receives. When theſe elaſtic emanations then flowing from the earth and moon meet in oppoſition to each other, will not their repulſion make the leſſer body recede from the greater, as an electrified ball from a charged conductor, not directly back like that ball or a comet, but obliquely in a gliding receſs from Perigeon ſimilar to its acceſs, as explained in the primary planets?

It will be allowed, that the earth and moon, as well as all ſpheres, are ſimilar bodies, as are alſo their centripetal and repulſive ſpheres. Their compoſition from analogy is alſo the ſame, therefore the depth of their atmoſpheres are alſo proportionable to each other reſpectively. Since then the earth, whoſe radius may be rated at 4000 miles, has an atmoſphere which is only computed 40 or 50 miles high, the moon's atmoſphere is ſcarcely 12, allowing her radius to be 1000 miles, and as at her diſtance this radius is reduced to an angle of 15 minutes, the height of her atmoſphere ſhould appear an hundred times leſs, ſuppoſe of 10 ſeconds of a minute, which is not ſo conſpicuous as a ſquare inch of pure cobweb at the diſtance of two furlongs. Therefore, altho' the moon, from the courſe of nature, muſt have an atmoſphere, it cannot be perceived by aſtronomers. And without conſidering the moon's concrete fires, her uſe in nature ſhews the neceſſity of a repulſive atmoſphere around her; for ſince, according to Newton, the repulſive emanations of body are more reflective of light than the bare ſurface of its matter, which may abſorb a part, the moon being an opaque body deſtined to ſupply the place of the abſent ſun, by a reflection of the ſolar light to us, ſhould be furniſhed with a repulſive atmoſphere, and indications of this are perceived in her diſk; for how otherwiſe when totally enveloped in the earth's ſhadow, as I ſaw her for above three hours in March 1783, could ſhe exhibit all the time of her immerſion the brilliant hue of an unſullied copper halfpenny, juſt freſh from the mint? And what elſe but the refraction cauſed by her atmoſphere will account for the ſudden immerſion of ſtar at her limb?

We have already remarked, that atmoſpheres of this repulſive warm matter, are of the ſame utility to planets as wool, hair, fur, and ſuch cloathing are to animals; for they molify the rigid cold of the celeſtial matter, and reduce the extreme preſſion thereof by an abſorption of it, as is the caſe when a fire is kindled in the ſun ſhine; for the beam conſuming a part of the influent nutrimental air, makes the fire dull and feeble. So the celeſtial matter in paſſing thro' an atmoſphere, is tempered by a reduction of its rigid aſperities, and becomes better qualified for terreſtrial purpoſes. Beſides, by preſenting a greater volume to the preſſure of the celeſtial matter, it increaſes the effect of that fluid on the planet, whereby it is retained in its orbit. The centripetal ſphere about planets, is alſo favourable to this preſſure; for experience ſhews, that the celeſtial matter pervades all bodies freely, whence the tenet with regard to gravity; the fiery concrete, in particular inherent in bodies, rather accelerates its ingreſs by rarifaction and conſumption than oppoſes it: wherefore it is its own ſpecies both influent into bodies and contextured in them, that is the chief obſtacle to its free paſſage through them; for different kinds of matter may be abſorbent and aſſimilative of each other, and therefore penetrative of each others ſubſtances, and accelerative of each others motions, as we have ſaid of the ſolar and celeſtial matters; but two parts of the ſame ſpecies cannot abſorb or aſſimilate, but are reſiſtive to each other, as we have ſeen in the electrified ſtockings of the ſame colour, and the emanations of poliſhed bodies, which are reſiſtive of light. Hence we ſaid, that ſuch effuſions ſent from the earth and its bodies to the celeſtial ſpaces in exchange for their matter, ſuſtain the commerce and traffic that ſubſiſt between the bodies of nature, preſerving their vigour and magnitude, and in aſcending thro' the atmoſphere, carry up with them ſmoke and flame, which are nearly, if not preciſely of the ſame nature with them. This ſuggeſts a poſitive cauſe of the aſcent of ſuch light ſubſtances very conformable to our ſyſtem which delights not in negative cauſes. The oppoſing parts then of the celeſtial matter alſo form an actual reſiſtance to each other's motions, in which the leſſer yields to the greater force: but the nether half of the moon's centripetal ſphere of this matter is in oppoſition to that which paſſes thro' her towards the earth, and therefore reſiſts it, which by the law of action and reaction, expreſſes the force wherewith ſhe is preſſed to the earth. But halves are as their wholes; therefore this half of her centripetal ſphere is as the whole, that is as her quantity of matter. And the ſame may be ſaid of the earth's preſſure towards the ſun, and of every body or particle of matter, with regard to their centripetal ſpheres, in reſpect to the neighbouring body in whoſe centripetal ſphere they are contained. For there is not a particle we can conceive of any compound body, or that can be taken or ſtruck from it, but has its concretes of the ſolar and celeſtial matters, and therefore has its centripetal and preſſive ſphere of the celeſtial fluid. Therefore, every body has the ſame in proportion to its quantity of matter, ſo that the preſſure on the moon, and all other bodies anſwers to the law of gravity collected from phænomena.

We have now aſſigned a centripetal and a centrifugal cauſe, acting on the moon and other ſecondary planets in the ſame proportion, mode, and propenſity, as do thoſe forces of the ſame principles which make the primary planets go round the ſun. But the primary planets move round orbits that are permanently ſtationed, and are urged by forces that have a conſtant ſupply of the actuating fluids, without any failure or loſs of theſe principles at any part of the circuit they deſcribe, *i. e.* the returning paths of each primary's circulations, are coincident in all parts. And hence it is, that their orbits may be ſtiled ſtationary, and the revolutions of each are performed in the ſame periodic times. This alſo would be the caſe with the ſecondary planets moving round their primaries, whether theſe were at reſt or in motion, if their periodical paths were in that manner permanently ſuſtained in all parts; becauſe the orbit of the ſatelite is compriſed within the centripetal ſphere of the primary. But the caſe is otherwiſe, the centripetal ſphere of the primary is not equally ſuſtained at all parts, as that of the ſun is on all ſides by the firmament, which ſurrounds him like a ſpherical ſhell. For in the ſyzigia line there is a vaſt difference between the forces that ſuſtain and ſupply the earth's centripetal ſphere, in oppoſition and conjunction, between which points it approaches to the form of an egg. And tho' the moon's orbit had been originally a circle, the cauſes which change the earth's centripetal ſphere to the form of an egg, would make the lunar orbit a ſection of it or an oval curve. Two or three examples will prepare the mind for this conception.

If a ſtone be thrown into ſettled water, the emerging waves will ſpread out and diffuſe in perfect circles; but in caſe of a ſtream, altho' they flow againſt it, they will be affected by the water's motion, ſo as to go more with the ſtream than againſt it, and therefore will not form perfect circles but ovals. I do not ſay ellipſes; becauſe the motion of their expanding waves will be retarded going againſt the ſtream, and therefore of a figure more bluntly round; whereas they will be accelerated on the ſide where the ſtream conſpires, and therefore of a more acute figure on that ſide. Again, ſound is ſaid to be propagated on all ſides of a ringing bell, by the air which flows off in the form of ſpherical ſhells that are concentric with, and expand as they recede from, the ſounding body. Doubtleſs theſe will be ſpherical in ſettled air; but if a wind ariſes, they will, inſtead of being truly round, get an egg-like form, whoſe broad end will be againſt the wind, which retards its motion on that ſide, and I apprehend, experiment will prove alſo, the oppoſite part of the ſounding ſpecies will be fartheſt from the bell, being urged on by the wind. The ſame may be ſaid of the centripetal ſphere of air that ſurrounds a ſmall fire, when placed within the limits of that which flows to a large ſtrong fire. The ſpace between both has a conſtant ſupply of air from the atmoſphere that feeds all the fires it contains; both fires therefore receive air from the ſpace between them, but the air of the intermediate ſpace wants of that native vigour it has abroad. And as this ſpace is compriſed within that, all whoſe air tends to the greater fire, the centripetal ſphere of the ſmaller fire muſt alſo ſtretch that way: and ſo in like manner does the centripetal ſphere of the earth tend towards the ſun, and gain an egg-like form, which conſequently muſt affect both the figure and poſition of the moon's orbit. For let S (pl. 3. fig. 1.) repreſent the ſun, T the earth, ◓◓◓◓ the moon's orbit with QCRO the earth's centripetal ſphere. The moon in conjunction, muſt yield in the direction of the partial cone; QCRS of the celeſtial matter, whoſe tendency is to the ſun, whereby her diſtance from the earth will then be increaſed. But at her quadratures Q & R, that diſtance will be leſſened by the action of the compleat cones X & Y, which in preſſing to the ſun, will preſs her towards the earth. And tho' the fruſtum F acting directly at O, ſhould ſeem to flatten the orbit in oppoſition, yet its preſſure there is not ſo great as are the preſſures of the compleat cones at the points Q & R, which are nearer to the ſun than O, by the radius of the earth's centripetal ſphere. But there is an additional cauſe why her diſtance from the earth will be increaſed in oppoſition, which will be underſtood from the following obſervations.

Suppoſe two bodies joined together by a contractile line, which may be affected by the ſmalleſt force, ſuppoſe that which carries a feather to or from an electrified body. Thus joined at a proper diſtance from each other, ſet both bodies afloat on the ſettled water of a pond, or any large veſſel moving either in a parallel direction, or one about the other, according to a certain law. The reſiſtence peculiar to water is not here admitted; becauſe the fluids we have in idea, and wherein the planets move, are both the vehicle and cauſe of their motions. While the water, then, is at reſt, and ſuſtained equally on all ſides, the bodies will continue their motion at a proper diſtance from each other, according to that law. Now bore a hole in the veſſel, or cut a paſſage in the pond for the water to run thro'. While the bodies are thus revolving about each other at their proper diſtance, that which happens to be next the perforation will immediately follow the ſtream and recede from the other, and continue to increaſe the diſtance between them, until the other gets into the ſtream alſo, and partakes of its motion: in this firſt caſe, we ſuppoſe the line between them to be in the direction of the ſtream, *i. e.*, as it were, in ſyzigies. Now, in the ſecond caſe, let the line between the bodies be rectangular to the ſtream: here it is evident that both being equally affected by the ſtream, they will move alike towards the perforation; but in their approach thereto, the diſtance between them will diminiſh by the converging motion of the ſtream; and ſo it happens with the moon and earth when ſhe is in either of the quadratures, and conſequently if ſhe be then in her Apogeon, the excentricity of her orbit will be diminiſhed.

Again, let her apſides be in the ſyzigies, when ſhe is either in conjunction or in oppoſition, and that excentricity will be increaſed. That it muſt be ſo, if ſhe be in conjunction, we ſaw before an account of the partial cone Q C R S, of celeſtial matter, which has a motion to the ſun, like that of water to the perforation. And for the ſame reaſon, if ſhe be in oppoſition, the earth being then next that flowing cone, or neareſt the perforation, muſt recede from her; ſo that in either the diſtance between the moon and earth will be increaſed when the moon is in the ſyzigies. Therefore in this line ſhe will exceed her proper diſtance from the earth, but in quadrature ſhe will come nearer to the earth than her proper diſtance. Conſequently in the intermediate octants ſhe will recover her diſtance; and by this contraction of her orbit in the direction of her motion her Apogeon will gain a progreſſive motion, ſo as to complete a period in about nine years, notwithſtanding ſome receſs thereof in the other octants, when approaching the ſizygies by encreaſing her diſtance, which receſs is counteracted by her own progreſſive motion. Theſe are the only perturbations the moon would be ſubject to were her orbit coincident with the plane of the eclyptic. But the plane of her orbit is inclined to the plane of the eclyptic, by an angle of a little more than 5°. Now, becauſe theſe cones of celeſtial matter, which affect her in preſſing to the ſun, converge towards that plane, they will act obliquely on the plane of her orbit, ſo as to affect its poſition and diminiſh her latitude, eſpecially when the nodes are about the quadratures, for then ſhe will have her higheſt latitudes in the ſyſigies, and this will be leſſened by that convergence which prevails thro' the deficiency of the partial cone Q ☾ R S. In her approach then to the plane of the eclyptic, ſhe will deſcend more directly, and to a point in the eclyptic more weſterly than before, and will therefore make a node nearer to the ſyzygy ſhe has left, than in her preceding revolution. Thus her node-line acquires a retrograde motion, until it falls into the ſyzygies, where it will be ſtationary for ſome time, becauſe the diſturbing cauſes there act in the continuation of the plane of her orbit as well as in that of the eclyptic; for which reaſon the poſition of her orbit and her latitudes will not be diſturbed during this revolution, nor much for ſome revolutions immediately before or after. However, as in the time of each revolution ſhe muſt attend the earth, which is moving eaſterly, ſhe will thus leave the ſun to the weſt; and as the cones that affect the poſition of her orbit preſs towards him, her node-line will again from their preſſure acquire that poſition with the ſyzygies that will renew its retrograde motion, whereby it finiſhes its period in the courſe of about 19 years.

By the ſame principle of motion the preceſſion of the equinoctial points may be explained, by which the ſtars change their longitude. It is proved by obſervation and experiment, that the equatorial parts of the earth are 17 miles higher than the polar. Again, the plane of the equator is inclined to the plane of the ecliptic by an angle of 23½ degrees, which would admit of an action of our celeſtial matter to change this declination more than that which changes the moon's latitude, were both equally diſtant from the earth's centre, in the proportion of the ſine of 23° 30′ to that of 5° 18′: but from affecting altitudes, this preſſure is above 14000 times greater on her. Wherefore, if ſuch preſſure does not change her latitude very ſenſibly, that which changes the equatorial declination ſhould entirely vaniſh; yet, as it is found by comparing together ancient and modern obſervations, that there is a receſs of the equinoctial points at the rate of a degree in 72 years ſimilar to that of the lunar nodes, whereby they deſcribe 360° in 19 years, both being ſubject to the ſame principles of action, and no other being admiſſible without a multiplication of cauſes to produce like effects; we muſt conclude that both retroceſſions ariſe from the ſame cauſe: and as that of the lunar nodes is chiefly effected while ſhe is in or near quadrature, ſo this of the equinoctial points is performed chiefly in or near the ſolſtices, by the eaſterly motion of the earth, both diurnal and annual, which leaving the ſun, unto which our celeſtial matter preſſes, to the weſt; every effect ariſing from ſuch preſſure muſt incline that way, and therefore the equinoctial points, as well as the lunar nodes, muſt turn to the weſt, or move contrary to the order of the ſigns.

The elevation of the land at the equator, which cauſes the foregoing effect, has been ſuppoſed by ſome philoſophers to proceed from the centrifugal force there particularly prevalent. The whirling motion of a body will, indeed, make water recede from its axis, and therefore it is ſaid, that the waters of the earth flow to the equator; and doubtleſs they would cover the whole torrid zone, if the lands were not higher than the elevation produced by this conflux. But the lands are not fluid; why then ſhould they riſe at the equator? It is ſuppoſed indeed that the earth was in a fluid ſtate, when the diurnal motion was impreſſed. But this is hypotheſis, and a treatiſe of phyſics ſhould be grounded on facts, not on the arbitrary conceptions of any man; at leaſt ours ſhall be founded on what we ſee and know from experience. All the bodies of nature we have ſeen, were made perfect and complete at their firſt formation; we therefore conclude, that the waters were gathered in their proper reſervoirs, and the earth framed in by its mountains and rivetments, which fix iſlands in their places, and bind continents together, before it got a diurnal motion; otherwiſe, that work which came perfect from the hand of Omnipotence, would have continued perhaps to this day a whirling chaos. Let us therefore conſult the operations of nature for a ſolution of this queſtion, conſonant to the real ſtate of things.

The ſolar and celeſtial effuſions with inert matter are concretes and conſtituents in every compound body. Theſe matters we have ſeen abſorb each other; and experiment ſhews, that a concocting heat contributes to connect them all together. Now more of the ſolar matter comes to the torrid zone than to any other part of the earth; therefore there is a greater concoction of thoſe matters there than at any other part of the earth's ſurface. Conſequently, the lands of the torrid zone ſhould be the higheſt in the world, as well as its mountains, as they are really found to be.

Again, as to the cauſe of levity there, we may ſay, that the reflection of light from any body is as its incidence, in the quantity as well as in the angle; therefore the loweſt region of the atmoſphere there will have more of this reflex light, and it will riſe higher there than at any other part of the earth. If not then from its reſiſtive power, at leaſt by its abſorption, this reflex light muſt diminiſh the preſſure of the celeſtial matter there, but not ſo much as it impoveriſhed the air coming to the fire. However, the aſcent of this reflex light may be an additional cauſe for the defect of gravity in thoſe parts in reſpect to the frigid zones. But there is another cauſe to be obſerved relating to pendulums that creates a difference with regard to the times of vibration in thoſe different parts of the world. For a ſhort pendulum will make a vibration in leſs time than a long one, and it is well known that the dimenſions of body expand by heat and contract by cold: therefore the regular pendulums of middle latitudes may lengthen at the equator by heat, and ſhorten at the poles by cold, as much as obſervers of true time find it neceſſary to ſtretch them in the frigid zone, or ſhorten them in the torrid. This may alſo affect the dimenſions of the different parts of the earth, ſo as to make the equatorial radius greater than the polar one by 17 miles; and beſides, if the equatorial parts are higher thro' an exceſs of ſolar effuſions, the polar parts ought to be lower thro' a defect thereof, not only to concoct the celeſtial matter in the frigid zones, but alſo to reduce its preſſure there. This preſſive power, without any centrifugal force, would be ſufficient to ſend the waters from thence to the equator, where the preſſure is leſs. The centrifugal force indeed may have ſome effect; but that the difference of that preſſure on the earth's ſurface is the ſole cauſe of the floods and ebbs of the ſea, will now fully appear.

We have ſeen that the centripetal ſpheres of our celeſtial matter, which ſurround bodies, are in the compound ratio of their magnitudes and concrete fires. Conſequently, that of the ſun is immenſely larger than that of the earth; and the centripetal ſphere of this matter, which ſurrounds the earth, is much greater than that of our moon; yet this laſt is ſo large as to reduce the preſſure of any cone of this celeſtial matter on the earth's ſurface. For we have ſeen that thoſe ſpheres are reſolvable into cones which preſs ſurrounding bodies to the central one. Again, as the primary planets within the ſun's centripetal ſphere revolve about him by ſuch preſſure, ſo the ſecondary planets revolve about their primaries by the preſſure of the cones of the centripetal ſpheres around theſe primary planets. Furthermore, as any primary reduces the quantity and preſſure towards the ſun of any cone of this matter, which it abſorbs, conſumes or transforms, ſo does the ſecondary affect the matter wherein it is enveloped with reſpect to its preſſure on the primary. Therefore, as the action of the partial cone Q C R S, fig. 1ſt. is leſs on the ſun than that of any complete cone X or Y of its centripetal ſphere, ſo the action of the partial cone q c r T, fig. 2d.

will be leſs on the earth's ſurface than that of any complete cone x or y of its own centripetal ſphere. But that the action of the partial cone Q C R S is leſs on the earth's ſurface, is evident from cauſe and effect. Firſt, its quantity was reduced by the earth's conſumption; and again the moon's orbit yields in conjunction, not being ſuſtained by that cone; ſo action and reaction being equal and contrary, as much as it wants of reaction to preſerve the figure of her orbit, ſo it wants of action on the ſun's ſurface: and ſo alſo will any partial cone q c r T in the earth's centripetal ſphere want of preſſure on the ſurface of the ocean in reſpect to any other of its cones. Conſequently the ſwells and floods of the ocean muſt be regulated by, and be attendant on the moon's motions round the earth, ſo as to riſe under her as in a pump thro' a defect of preſſure. And this is the fact found by experience, with this difference, which is uſual in material operations that the effect follows the cauſe. The waters therefore of any meridian riſe ſome time after ſhe has been there, and flow after her as ſhe recedes from the different meridians towards thoſe parts of the earth's ſurface to which ſhe is ſucceſſively vertical in her daily and monthly motions. Moreover, on account of the defect of preſſure in the partial cone QCRS between the ſun and earth, both in action and reaction, the waters will riſe ſomewhat in the univerſal meridian and follow the ſun; ſo that from both cauſes concurring together, the tides are higheſt at the conjunctions and oppoſitions of the moon; but will be leaſt in the times of her quadratures, when the quantity aſcending to both luminaries is ſpread thro' a greater ſpace, as it were in a wide veſſel in reſpect to a narrow one.

Thus far, if we abſtract from the difference between a real known cauſe and an ideal one, our theory agrees with that of attraction. But we muſt depart from the reaſoning of that ſyſtem, both as to the cauſe of a ſecond tide in 24 hours, and as to the extent of the ſwell from pole to pole. To begin with the latter attraction between two bodies, is conceived to act in a line between their centres; that between the ſun and planets, for inſtance, acts in the line called the radius vector, and were the moon even in contact with the waters, her attracting power, to judge from univerſal experience, ſhould only raiſe the waters ſo far as the extent of her body; for an horſe when drinking only raiſes what water goes into his mouth, and a pump, a ſiringe, or a capillary tube, only raiſes water to the extent of it's aperture. But at her preſent diſtance, the polar waters are in a quadrantile ſituation, ſometimes more and ſometimes leſs, according to her declinations, and therefore, according to the principles of attraction, ſhould be always depreſſed; and even nearer the equator, it is ſometimes not eaſy to reconcile their elevation with thoſe principles. As for inſtance, during the winter ſolſtice, let the moon, then ſuppoſe in conjunction, have her greateſt latitude, ſhe would then have a declination of near 29° S. Conſequently all places more than 50° N. L. would be in or near a quadrantile ſituation with reſpect to her, how then can thoſe places in our hemiſphere and latitude have a tide during the day, even allowing them to have an oppoſition tide during that night? But in our ſyſtem the moon's centripetal ſphere, whoſe diameter muſt be at leaſt 20 times the diameter of the earth, and may be vaſtly more, has amplitude enough to reduce the preſſure on water to the extent of the earth and beyond it.

Again, as to the ſecond tide, where there is ſuch a gravitation to the earth, as gives the waters of the ocean a ſpherical form, and alſo an attraction of coheſion whereby theſe waters ſtick to the earth, it is ſtrange that the attraction of the moon ſhould act ſo powerfully, not only on the earth's centre, but upon all ſtrands and coaſts, as to draw them down below the waters, and thus produce a relative elevation of the latter, which in fact is the real explanation of the 2d tide by attraction. But having refuted the principle, it is needleſs to diſcuſs the ſolutions founded upon it, let us therefore ſeek for a cauſe of the 2d tide, conformable to nature and experience.

Suppoſe the moon in oppoſition and vertical to the iſland Otaheite, or there-abouts, in the great Pacific ocean, the ſuperiour preſſure of all the complete cones of celeſtial matter that act on the earth's ſurface, would drive the waters from the weſtern coaſts of America, the eaſtern coaſts of Aſia, the Ladrone iſlands, New Holland, and the ſouth pole towards the partial cone under the moon, at the middle part of that ocean where the preſſure is leſs, ſo as to form an high tide at Otaheite, and all round that cluſter of iſlands. The ſun would then be vertical to the central part of Africa, and for the ſame reaſon the waters of the Atlantic would be driven from the coaſts of America, and thoſe of the Indian ocean ſhould be driven from the coaſts of Aſia, New Holland, and more from the ſouth pole to the coaſts of Africa toward the partial cone under the ſun. At that part of the world then and its ſurrounding coaſts, the waters muſt riſe thro' the defect of preſſure in that partial cone, for which reaſon the tides are high along theſe coaſts. Now if theſe luminaries recede from theſe places, or vaniſh, will not the waters to reſtore the equilibrium they had loſt, by their being ſo collected and thus heaped up, fall to their own beds, and even deſcend lower there, ſo as to leave naked and dry ſtrands about that cluſter of iſlands and the coaſts of Africa, and by the force of that deſcent, be driven as it were like a pendulum, ſo as to raiſe other parts of the ocean to the ſame height on the coaſts of Aſia and America, from whence they were before driven, and where they muſt now ſtop, being hemmed in by the latter as far ſouth as Cape Horn, and by Aſia and its iſlands, as far as to the ſouth of New Holland, and if there be any other lands more ſoutherly? And here again, when they riſe to their greateſt heights, muſt not they fall back again and riſe to their former elevations in the middle of the Pacific ocean, and the coaſts of Africa, by that vibratory motion, eſpecially as water is elaſtic; (ſee our third lect.), and ſo like a pendulum, continue theſe vibrations in going over thoſe ſpaces of near 90° each, whereby the ſpherical figure of the ocean, when ſtagnated, by the rarifactions of the ſun and moon, becomes an oblong ſpheroid, alternately pointing to, and falling from them every 12 hours? So the circular periphery of a large bell, by the ſtrokes of its clapper, becomes an interhanging ellypſe, whoſe longeſt diameter changes to rectangular poſitions; as do thoſe of the ſpheroidical floods, whoſe vibrating ſpaces are as near 90° as the barriers of the earth will admit of: conſequently the intervals of time between the returns of ſuch tides to the ſame places, ſhould be about 12 hours, when ſo attendant on bodies that go round the earth in 24 hours.

But the vibrations of a pendulum will leſſen, and at length ceaſe, if they be not renewed, and after they are renewed by a touch of the finger, they will continue for ſome time, and leſſen as before; yet by a ſtroke, time after time, its vibrations will continue for any length of duration. So the bell, by two ſtrokes of the clapper, will get the vibrations of a changeable ellypſe, which will alſo leſſen and ceaſe if not renewed now and then; and if the place of the ſtroke is changed regularly round the bell, the rectangular diameters of its changeable ellypſe will follow that order; for every effect will follow its cauſe. So, after the ſpheroidical figure of the waters is formed by the oppoſite poſition of the ſun and moon; if both ſhould vaniſh, the waters being elaſtic, (ſee III. & V. Lectures) would vibrate in their ſpheroidical change of rectangular diameters, and continue for a while; but in ſome time, like thoſe of the bell, their vibrations would ceaſe, but would again be renewed by the return of either cauſe. Let the moon only return and follow her courſe, and her preſence will keep up thoſe ſpheroidical vibrations of the water, whereby they riſe and fall in the ſame places every 12 hours, *i. e.* 6 hours falling and as many riſing thro' thoſe ſpaces of 90° each: and the rectangular diameters of this changeable ſpheroid, ſhall follow the order of her motion, as did the rectangular axis of the changeable ellypſe follow the ſtroke of the hammer round the bell. And tho' it were poſſible for the order of the latter to change, it is impoſſible for the order of the former to change, eſpecially in thoſe oceans which are bounded by theſe meridional barriers, where the power induced by her preſence is renewed ſucceſſively every 24 hours, or at every ſecond tide. Now what can the ſun do here, whoſe power is much leſs than her's, but to unite his cauſe with her's, to croſs it, or to oppoſe it directly? The 1ſt makes no alteration but to encreaſe that flood that follows her by the union of both powers, which ſhall be together exerted in every ocean in the courſe of one day. A ſeparation of thoſe unequal powers at or near a rectangular poſition, will ſerve but to leſſen the floods, whoſe conatus muſt follow the greater power; and if there ſhould be any other ſlight change thence ariſing, the next oppoſition will regulate them, and renew the oppoſite tides in their proportions as at firſt. Thus all the motions of the ſeas are wound up every 15 days, and perfectly regulated at every full moon. We mind not the difference of time wherein tides happen on the ſame coaſts, in gulphs, bays, ſtreights, or inland ſeas, they are but moveable parts of the ſame body of waters, and their times depend on their poſitions and diſtances from the great primary floods, which may increaſe or diminiſh the number of vibrations, and thus multiply, accelerate, or retard tides in places complicated with iſlands, and communicating with different ſeas.

SECTION III.

The Phænomena of Gravitation, and thoſe imputed to Attraction of Coheſion ſolved by the ſame material Cauſes.

WE are now fully prepared for the ſolution of Gravity and Coheſion; for having ſeen that every body in nature, or even the moſt minute particle that can be ſtruck off or ſeparated from a body, contains its proportionable part of the ſolar, celeſtial, and inert matters; it follows, that every ſuch body or particle muſt be ſurrounded by a centripetal ſphere of celeſtial matter, proportioned to the quantity of its ignious concrete, *i. e.* in a general man-

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ner proportioned to its quantity of matter. This celeſtial matter, being by eſſence convergent, is penetrative of all bodies; fire in particular, we have ſeen, rather accelerates its motion than ſtops it; and as for inert matter, it has neither power nor property to impede the progreſs of this univerſal fluid. The motion of this matter through bodies is therefore only reſiſted by a counteraction of its own ſpecies: wherefore its preſſive action on any body, being as that reſiſtence, muſt be as the centripetal ſphere ſurrounding that body, and as the quantity of its own ſpecies contextured therein. So far have we before illuſtrated this ſubject, and thence concluded, that the action of the celeſtial matter preſſing the planets to the ſun, ſecondaries towards their primaries, or terreſtrial bodies towards the earth, anſwers to the law of the phænomena, and is as the quantity of matter.

But we are now to obſerve, that in as much as the concave ſurface of the firmament, that contains the ſolar ſyſtem is immeaſurably larger than the ſurface of the ſun, ſo muſt we conclude, is the quantity of the celeſtial matter flowing thro' this vaſt expanſe greater than

than the quantity of his emanations. And this proportion is confirmed by experience; for how immeaſurably greater is the force of gravity on bodies at the earth, of which the celeſtial matter is the cauſe, than that of the ſolar light! The ſuperiour force and quantity of the celeſtial matter may be judged of by the velocity of falling bodies. Nor did the neceſſity of this ſecond fluid more ſwift and forcible than light, cauſing its vibrations, reflexions, and forcing it through bodies, eſcape the ſagacity of Sir Iſaac Newton. (See 18 Query.) ‘ Is not, ſaid he, the heat of a warm ‘ room conveyed through the vacuum by the ‘ vibrations of a much ſubtiler medium than ‘ air? And is not this medium the ſame with ‘ that medium by which light is refracted and ‘ reflected, and by whoſe vibrations light ‘ communicates heat to bodies? And is not ‘ this medium exceedingly more rare and ſub‘tile than the air, and exceedingly more elaſ‘tic and active, and doth it not readily per‘vade all bodies? And is it not (by its elaſtic ‘ force) expanded thro’ all the Heavens, &c.’ This medium he conſiders as the cauſe of light’s refraction, of which he treats in his 12th Prop. 2d B. of Opticks; for he ſaw it’s neceſſity, tho' he had but a very imperfect notion of its nature, neither defining it, nor ſhewing its ſource or propenſity, but concluding the prop. thus: 'Whether this hypotheſis be 'true or falſe, I do not conſider, I content 'myſelf with the bear diſcovery, that the rays 'of light are by ſome cauſe or other alternate'ly diſpoſed to be reflected or refracted for 'many viciſſitudes.' See again his conceptions of this medium and its velocity in his 21ſt query, where he ſeems to have approached to an idea of our celeſtial matter, but was diverted from it by a miſinterpretation of the unuſual refraction of Iſland Chryſtal; which, with his ſuppoſed vibratory ether, the natural offſpring of particles doubly endowed with attraction and repulſion, was a bar to his arriving at the diſcovery of our celeſtial matter, which is nature's real, univerſal and predominant principle, of which he gained but a very imperfect glimpſe in the hypotheſis of his ether. From the univerſality then, and unſpeakable ſwiftneſs of the celeſtial matter, the quantity of it pervading any body muſt be immeaſureably greater than the quantity of it therein contextured, and thefore the part of it that meets with interruption in flowing thro' body, as for inſtance thro' the roof or floors of an houſe, is ſo ſmall with reſpect to what paſſes thro', as to cauſe no abatement of its action on the pen in my hand, or on a body in the cellar, no more than if either was placed in open ſpace. Hence alſo the well known experiment of a piece of gold and a feather falling with equal velocities in an exhauſted receiver. This experiment is generally adduced to prove, that gravity acts on bodies in proportion to their quantities of matter, which we agree to; but it is alſo produced as a proof of a vacuum; in this reſpect, we ſhall examine the uſual method of reaſoning on it, which we ſhall take from Dean Hamilton's Lectures, (p. 79). 'If the region of the air, for inſtance, 'were filled with any matter that had no empty 'pores, let this matter be ever ſo ſubtile, or 'ever ſo fluid, it muſt ſtill have a greater den'ſity, and conſequently a greater ſpecific gra'vity than quickſilver or gold; ſo that it would 'be as impoſſible for even the heavieſt bodies to 'deſcend in this fluid as it would be for a cork 'to deſcend in water, or wood in quick ſilver. 'And ſince bodies, which in the open air are 'reſiſted in very different degrees, fall together 'in an exhauſted receiver, without any ſenſible 'reſiſtence, it is concluded that ſuch a receiver 'doth not contain in it any matter that hath 'either a ſenſible gravity, power of reſiſtence 'or vis inertiæ, or in other words, that it doth 'not contain any ſenſible matter at all. It is 'therefore incumbent on thoſe who aſſert, that 'all ſpace is equally full of matter, to tell us 'what kind of matter it is that adequately fills 'a receiver exhauſted of air, and to ſhew its 'properties, ſince it is evidently diveſted of 'thoſe properties that are common to all bodies 'we know of.'

This indeed is an objection, which might have room againſt Newton's ether, and againſt other mechanical ſyſtems adopted for the ſolution of electricity and gravity; but it has no place againſt our celeſtial fluid on account of the preſſive motion and convergent propenſity which is eſſential to it, but no wiſe analogous to the etherial or electrical fluids. Our celeſtial matter fills all ſpace, ſo that there is not a conceivable point, even at the concave ſurface of the firmament, from whence it effuſes, where it is not preſent, and in a ſpiſſitude of ſubſtance equal to the denſity of light at the ſun's ſurface; for we have no reaſon to think there is a difference. This matter therefore is in immeaſurably greater denſity throughout ſpace than it is in the compoſition of bodies, which are porous, and contain their proportional quantities of other concretes. On the ſurface of the earth then, or in a receiver exhauſted of its air, this matter is more denſe than gold, which is a porous and compound body. Therefore concludes this author, *it is as impoſſible for gold to deſcend in this matter, as it is for a cork to deſcend in water, or wood in quick ſilver.* Truly if this matter were ſtagnate, or only vibratory as the ether, that would be the conſequence. But this fluid itſelf is in conſtant motion towards the earth, and bears all bodies down in that direction, in proportion as it meets reſiſtence in paſſing through them. It is therefore as impoſſible for gold or any other body, in which much of this matter is contextured, not to deſcend with it, as it would be for a cork not to deſcend, while it is immerſed in the falling torrent of a cataract; and every one will allow that the inferiour ſpecific gravity of a cork would not enable it to riſe againſt ſuch a torrent.

As to the properties of this matter, which Mr. Hamilton pronounces it incumbent on us to aſſign, they have been already explained and fully proved; we need only remark here, that it has two of thoſe mentioned by that author, *to wit*, action and reſiſtence, for it is the cauſe of deſcent in all bodies, and it retards, and at length deſtroys all the motion of an aſcending body, tho' it ſhould have all the impetus it could receive from a cannon royal. However it has not vis inertiæ, nor is that property eſſential to all matter. (See our 2d lect.) We ſhall now conclude with a few confectaries reſulting from our theory, which ſhew it's agreement with phænomena, and lay a foundation for practical application.

SCHOLIUM.

Whenever one body gravitates towards another, its centripetal ſphere muſt be contained within that of the other; for we have ſeen, that the action of the celeſtial matter upon a leſſer body producing gravitation towards a greater, proceeds chiefly from the reſiſtence which the celeſtial matter flowing to the greater meets in paſſing thro' the leſſer and its centripetal ſphere; therefore, that centripetal ſphere muſt be within its influx, *i. e.* within the centripetal ſphere of the greater body. Therefore, the centripetal ſpheres of the moon, and all terreſtrial bodies are compriſed within the centripetal ſphere of the earth.

COROLLORY I.

HENCE we ſee why ſteeples and houſes ſtand firm on their foundations on all ſides of the terraqueous globe; why the ocean preſerves a ſpherical ſurface; why ſhips and men with us, with our periœci, antœci, and antipodes retain all together an upright poſition; whence the facility of ſailing round the world.

CORROLLORY II.

SINCE the preſſive action of the celeſtial matter is ſucceſſive and conſtant, if we ſhould divide it into impulſes as time is divided into moments; theſe impulſes, on any deſcending body will be as the moments during its fall, in which proportion its velocity will increaſe. Conſequently in different bodies deſcending freely, theſe impulſes will in equal times generate equal degrees of velocity, and therefore the velocities acquired by bodies falling freely will be as the times elapſed from the commencement of the fall.

CORROLLORY III.

SINCE the ſpaces deſcribed by the ſame or different bodies are in the compound ratio of their times and velocities, and that the velocities in bodies falling freely are as the times elapſed, the ſpaces deſcribed by ſuch bodies will be in the duple ratio of either the times from the commencement of motion, or the velocities acquired at the end of the fall.

From the two laſt corrollories, as from radical and univerſal theorems, all queſtions relating to the motion of bodies, as well aſcending as deſcending, as well obliquely as perpendicularly, may be ſolved, if duly conſidered and applied; and they may be extended, varied, and illuſtrated by geometrical and arithmetical applications after the uſual manner: a further detail of conſequent theorems would not be conſonant to the nature of this work, which is an inveſtigation of firſt principles, we ſhall therefore paſs to the ſolution of the principal phænomena and experiments of attraction by coheſion; for here alſo our material principles are the real agents.

The phænomena generally conſidered under this head, conſiſt principally of experiments exhibiting an adheſion between liquids and ſolids, and the parts of each. But theſe things are now ſo clear, from our principles, as to need little illuſtration. For we at once perceive the power of our centripetal ſpheres of celeſtial matter in preſſing water into bodies, whereby ſome are filled, as ſponges and cloaths, others diſſolved, as ſalt, ſugar and earth, and others only wetted by the water, which the influent matter in paſſing to their fires attaches to their ſurface. From the force wherewith this matter converges to the interiour fires of bodies, two contiguous drops of water are driven together; and the centripetal ſpheres of this matter that ſurround drops of mercury, being more large and prompt in their propenſity, on account of the ſuperiour quantity and vigour of mercurial fires, drops of that ſubſtance are influenced to approach from a greater diſtance than thoſe of water. But the cauſe of acceſs in both caſes is the conſumption and reduction of the intermediate column of celeſtial matter by the fires on both ſides of it, while its preſſure is continually ſuſtained on the exteriour ſides, ſo as to make them coaleſce. The intermediate column of this matter is in like manner abſorbed and reduced between two floating glaſs bubbles, wherefore they likewiſe approach and ſtick together, the ſame of all other floating bodies; but as leaden bullets are not qualified to float, to render this preſſure on them ſenſible, a plane is made in each by cutting off a little, theſe planes being preſſed together with a gentle twiſt they will adhere to each other with great force, as will poliſhed plates of wet glaſs, &c. All theſe experiments will ſucceed in an exhauſted receiver, the air being excluded; the preſſure of the celeſtial matter, muſt therefore be the cauſe, for no other fluid ſubſiſts in that pneumatic vacuum

Again, if a piece of glaſs, or any body, containing more fires in its conſtitution than water does, be immerſed in that fluid, it will be ſurrounded by a fillet of water elevated above the reſt of the ſurface; becauſe the celeſtial matter at that part of the water next the immerſed body will turn to the body of ſuperiour fires, as it does in the formation of centripetal ſpheres, and entering the glaſs by the ſhorteſt way leaves the part of the water immediately round the immerſed body leſs preſſed than the reſt of the ſurface, which part therefore riſes higher and forms a fillet, which is preſſed againſt the ſide of the immerſed body by the influent matter. On account of this elevated fillet round the ſide, water in a ſlender drinking glaſs will have a concave ſurface, and the elevated part will be ſtrongly urged againſt the ſide of the glaſs by the celeſtial matter, which preſſes perpendicularly (*i. e.* like all other fluids by the ſhorteſt way) into the glaſs to ſupply for its rarefaction there, and reſtore the equilibrium of its parts. This ſtrong preſſure of the elevated part of the fluid is very ſenſible on diſſolvable bodies, as ſalt, ſugar, clay, &c; for ſuch bodies having been for ſome time partly immerſed, you will find them remarkably waſted and worn under that fillet of elevated water. And hence we ſee the natural cauſe that wears and diſſolves the banks, walls, and rivetments of ponds, ditches, &c. more at the water's edge than under or over. This has been commonly attributed to waves and ſuperficial agitations, but ſuch waves cannot be imagined in a tea cup, where a piece of ſugar is partly immerſed, or in a ciſtern of rock ſalt, in a piece of which I have ſeen an inciſion an inch deep made all round it at the ſurface of the water in a few days time. And as the celeſtial matter forces water into bodies, and thereby diſſolves ſome, ſo alſo it carries with it air, light, and every kind of fluid that falls in it's way, for which reaſon all theſe collectively we have called influent matters. Light is particularly ſubject to its preſſive action, whence the real cauſe of its refraction, and of its not paſſing thro' bent tubes; for in its paſſage, it is forced into the ſurface of the tube and totally abſorbed, otherwiſe it might, by ſucceſſive reflexions paſs to the other aperture. Whence here, as well as in the heavens, this matter is the cauſe of light's abſorption and of darkneſs.

The action, whereby the celeſtial matter joins bodies together, explains why a tint of ink, or a drop of liquid ſticks to a writing pen, or is retained by a narrow tube, and why a veſſel of glaſs or any other ſubſtance, being filled with water, ſupports a ſwell or an accumulation above the brim. For the preſſure of the influent matter binds the verge of the liquid heap to the edge of the veſſel, which, along with the action of the centripetal ſphere about both, hinders the prominent liquid from flowing over, until the weight of the quantity accumulated becomes ſuperiour to the force, whereby both verges are faſtened together. For the ſame reaſon, the water raiſed by any narrow tube, is by the influent matter ſo bound to the loweſt annulus, that it will not only ſupport a quantity within the tube, but alſo a drop ſuſpended from it.

This preſſive action alſo makes a glaſs bubble floating in a glaſs veſſel of water adhere to the ſide, while the veſſel is not full; but when it is ſo filled as to have a ſwell of water over its brim, the action of the celeſtial matter, being in a direction perpendicular to the now convex ſurface of the glaſs and water, will force the bubble to move up to the vertex, but not there to vibrate or go farther; for it there meets the action of the ſame matter in a like tenor from the oppoſite ſide; wherefore the bubble will reſt upon the vertex.

All theſe experiments correſpond with what we remarked in electrical experiments, and with the lemmas eſtabliſhed in the preceding lecture; for according to the quantity of fire collected in the prime conductor, ſo was the influx of celeſtial matter thereto: and hence we ſhould infer, that of various contiguous bodies, differently contextured with fires, that, which contains moſt with reſpect to its other concretes, will likewiſe have the greateſt influx of this celeſtial matter. The truth of which ſhall now more fully appear. Let two plates of glaſs be ſo erected in water as to concur at one ſide, forming an angle which will ſeparate their other ſides a little diſtance; the water between them will riſe at different parts to heights that are inverſely as the diſtances between them at thoſe parts. For the fires of glaſs being greater in reſpect to its other component matters than thoſe of water with reſpect to the other concretes of that fluid, moſt of the celeſtial matter which comes between the plates will be abſorbed where the interval is ſmall by the fires of the glaſs, ſo that little or none of it gets ſo far as the intervening water to preſs it down. But at other parts, where the intervals are greater, more of it will reach to the water between the plates, and depreſs the liquid there, which to reſtore its equilibrium, muſt riſe higher towards the concourſe, where the preſſure on it is leſs. Therefore it will ſtand higheſt of all at the concourſe, where the fires of the glaſs abſorb all the preſſive matter; and the more diſtant from the concourſe, the leſs high will the intervening water be, becauſe the ſmaller proportion of preſſive matter is abſorbed, until it comes to the common level of the exteriour water, where the intervals between the plates are ſo great as to admit a ſufficiency of this matter to depreſs it to that level.

For the ſame reaſon it is, that in glaſs tubes the heights of the elevated water will be inverſely as their diameters. But in fine capillaries, the heights of the water raiſed will exceed that ratio; becauſe all the preſſive matter that reaches to their bore is entirely devoured by the fires of the glaſs; whence we might infer, as perhaps future experiments will prove, that the weight of water, as well as that of air, depends on the action of this preſſive matter. Again, when the tube is very wide, the height falls very ſhort of the above ratio, the internal water being preſſed down to the common level, except immediately round the ſurface of the tube, where the preſſure is diverted from the water to the glaſs, by whoſe fires the preſſive matter is more conſumed, and to which therefore it muſt flow with greater propenſity to reſtore its equilibrium; whence the elevated fillet ſpoken of before.

In all theſe experiments, the fires of the liquid were inferiour to thoſe of the ſolid, and therefore there was a greater influx of the celeſtial matter to the ſolid body; let us now invert the caſe, and we ſhall again find the celeſtial matter follow the more abundant fires, as clearly as we perceived that propenſity in the experiments of electricity. For let the ſame plates be erected in the ſame poſition in mercury, the phænomena of elevation between the plates will be entirely reverſed: for as a piercing ſtream of air will flow through a cracked pane of glaſs, a crevice, or key-hole into a warm room more forcibly than thro' the door or window, when open; ſo at the ſmalleſt intervals between the plates, the celeſtial matter preſſes with greater force to the mercurial fires, which are in that ſubſtance greater with reſpect to the other concretes, than they are in glaſs. Wherefore the current of this matter now ruſhing to the more vigorous fires of mercury in preference to thoſe of glaſs, being in greater quantity between the plates (in reſpect to the interval) at or near the concourſe than it is at greater diſtances, is more condenſed and ſtraightened at thoſe ſmaller intervals, and therefore preſſes down the mercury more forcibly there than at the wider ones, ſo as to form depreſſions of the mercury at and near the concourſe correſponding with the elevations of the water in the foregoing experiment. For the ſame reaſon the phænomena of capillary tubes, when mercury is employed, are the reverſe of thoſe, when the experiments are made with water. Whence we ſee how the ſame primary cauſe, tho' acting according to the ſame law and propenſity, will from different circumſtances produce oppoſite phænomena. Here the difference was only, that in one caſe, the fluid between the plates was more impregnated with fire, than glaſs is, in the other caſe, leſs.

A column of mercury will be ſuſpended to the height of 60 or 70 inches in a narrow glaſs tube, altho' the preſſure of the air will only ſuſtain it to the height of 31 inches. The reaſon of which is, that in this cylindrical tube, the influx of the celeſtial matter is alike forcible at both ends, and produces a counteraction: beſides the ſolidity of the mercury in ſuch a tube being very ſmall in reſpect to its ſurface, which lines that of the tube, it's fires thus extended and confined, may be conſidered as the concrete fires of the glaſs; but more conſumptive of the celeſtial matter, which to reſtore the equilibrium continually deſtroyed within, will in paſſing thro' from all ſides bind this mercurial core to the glaſs, as it bound together the meeting verges of the glaſs and heap of water in a foregoing experiment. In like manner, water may be retained to any height or length of time, not indeed from the power of it's fires as here, but from their deficiency in reſpect to thoſe of glaſs; whereby it eſcapes evaporation, and remains confined without any influx of the air or celeſtial matter, which may be further illuſtrated in the ſolution of another curious experiment.

Let a drop of water be put into the wide end of a conical tube, but ſo large as to touch the interiour periphery of the glaſs all round, and the drop will flow to the narrow end in every poſition. For all the celeſtial matter that ſhould enter at the ſmall end is entirely abſorpt by the fires of the glaſs, ſo that none paſſes to the water to preſs the drop from that end; but at the wide end enough enters to act on the drop, beſides what the glaſs conſumes; wherefore the drop is forced, and muſt flow to the ſmall end and remain there. On the ſame principle alſo is clearly explained, that extraordinary phænomenon of capillary tubes, quoted in the Phil. Brit. p. 29, v. 1. where much pains are taken by mathematic and mechanic reaſoning to reſolve it by attraction. If a large bored tube be at one end drawn out into a fine capillary, ſuch a tube filled with water, and then inverted into a veſſel of water, will retain all the water ſuſpended through it's whole length, if it does not exceed the height to which a capillary of the ſame bore will attract it. One ſhould imagine that the capillary, tho' ſmall, would admit air enough to preſs down the water to the common level; or if the paſſage were ſuch as would not immediately permit the preſſure of the atmoſphere, at leaſt that in proceſs of time a ſufficiency of air might get in to preſs down the water. But the caſe is here as in the other capillaries, all the celeſtial matter that comes to the tube is abſorpt by the fires of the glaſs, except what ſuch a bore will give a paſſage to without interruption; and in as much as this is leſs in quantity and preſſure than that on the external water, ſo much more elevated muſt the internal water be than the external. Thus we find in every experiment what we ſignified in our theory of tides, viz. that where the celeſtial matter preſſes leaſt, there the waters will be moſt elevated, and converſely. Hence alſo we gather, that the celeſtial matter that blends with air is the real cauſe of its preſſure; for every one will allow, that air is found in bodies and places, where the pores and interſtices for its admiſſion are ſmaller than the bores of capillary tubes, or the ſmaller intervals between the plates where the water ſtands ſo high. Conſequently in a length of time a good deal of air is admitted by the ſmalleſt capillary; but as the water ſtill ſtands ſo high, we muſt conclude, that this influent air muſt have loſt it's weight or preſſure: and how can this be unleſs its weight or preſſure depended on the celeſtial matter in its compoſition, which turned into the fires of the glaſs, to reſtore the equilibrium deſtroyed by their conſumption?

To aſſign a phyſical cauſe for the firmneſs of natural bodies, is a ſubject which naturally preſents itſelf here, and which has exerciſed, and indeed baffled the ingenuity of philoſophers both antient and modern. To convince the reader of this, it is not neceſſary to enumerate their various ſyſtems; Sir Iſaac Newton's authority will ſuffice. 'The parts of all homogeneal bodies (ſays this great man, 31ſt qu.) which fully touch, ſtick together very ſtrongly. And for explaining how this may be, ſome have invented hooked atoms, which is begging the queſtion; others tell us that bodies are glued together by reſt, that is by an occult quality, or rather by nothing; and others, that they ſtick together by conſpiring motions, that is by relative reſt amongſt themſelves. I had rather infer from their coheſion, that their particles attract one another by *ſome force*, which in immediate contact is exceeding ſtrong, at ſmall diſtances performs the chymical operations above mentioned, and reaches not far from the particles with any ſenſible effect.' Whether this *ſome force* of the author be an occult quality or not, I ſhall not determine; but from the futility of the cauſes aſſigned, it appears that no ſatisfactory ſolution of this queſtion has yet been hit upon by philoſophers.

It is known from experience, that it is very hard, if not impoſſible, to clear up any difficulty that is founded on chimerical or inconſiſtent principles. Therefore, before a philoſopher ſets his invention on the ſtretch to anſwer a phyſical queſtion, he ſhould examine the reality of the principles the queſtion is founded on, otherwiſe an imagination fertile in chimerical ſuppoſitions might carve out work for all the philoſophers in the world, and broach innumerable queſtions never to be anſwered. Now the difficulty of the preſent queſtion ariſes from the received but inconſiſtent ſuppoſition, that all matter is of one kind, and that *God in the beginning made it in the form of hard, impenetrable moveable particles, of certain ſizes and figures*, &c. (ſee Newton's laſt quere). This opinion, with little variation, has prevailed in moſt phyſical ſyſtems ſince Democritus, and after him Epicurus broached their atoms and gravity, at leaſt Sir Iſaac ſeems to have adopted it upon the *authority of the oldeſt philoſophers of Greece and Phœnicia, who made vacuum and atoms, and the gravity of atoms, a firſt principle of their philoſophy*, 28 qu.

But the impenetrability of particles we have already arraigned, ſee lect. 6, where we proved light a continuum, and concluded, that the

Creator of ſubſtances was not in the beginning confined to any particular form, texture, ſize or conſiſtency: wherefore experiment and obſervation of nature were to decide how he created matter, independently of the conceptions of philoſophers, whether ancient or modern. The celeſtial matter alſo, from its univerſality, flowing motion, and effects in the conſtitution of body, we have alſo reaſon to pronounce a continuum. For there is no experiment to prove the contrary; and hard impenetrable particles of this or any other kind of matter would be as gravel in the fluids of nature; they would prevent that continuity of ſubſtance both fluid and ſolid, to which earth and all the other component matters of glaſs are reduced, ſee lect. VI. & VII, and render impoſſible the perfect ſolution of the three elementary matters in the oils, juices, and ſpirits of vegetables, which is neceſſary for their tranſparency. This property is alſo inconſiſtent with attraction, taken as a phænomenon, for (abſtracting from the abſurdity of that power) even the appearance of ſucking or attracting we have ſeen to be impoſſible in any body that has not a power of rarifying ſome place for a fluid to enter into by preſſion;

conſequently ſuch an operation is inconſiſtent with poreleſs impenetrable particles, and therefore overturns the conjecture which Newton forms about the coheſion of bodies in the ſame query, where he ſpeaks thus: 'The ſmalleſt 'particles of matter may cohere by the ſtrongeſt 'attractions, and compoſe bigger particles of 'weaker virtue, and many of theſe may cohere 'and compoſe bigger particles, whoſe virtue is 'ſtill weaker, &c.'

The figures of particles, upon which preſent writers lay ſo much ſtreſs in treating of coheſion and other qualities of bodies, as to affirm that 'ſeveral things of moment depend on this 'property, for that according to the ſeveral figures of corpuſcles, they will touch by a greater or leſſer quantity of ſurface, and ſo will cohere more or leſs firmly together; from hence 'will ariſe various qualities of bodies, which are 'the foundation of moſt of the conſiderable 'phænomena of nature, &c.' Phil. Brit. vol. I. p. 8, that principle, I ſay, is alſo hypothetic and totally defective; for it depends on the abſtract idea, formed of matter, by which it is reduced into particles, a notion arbitrarily and raſhly conceived. If figure, which is but a mode of being regarding only the ſurface of body, was a cauſe or ſource of qualities, pounding, breaking, and carving bodies and their parts would be the moſt direct and efficacious means of changing or ſuperinducing powers and qualities, inſtead of thoſe methods uſed by chymiſts, dyers, &c. in all which it appears that the change or ſuperinducement of qualities depends on the loſs or acquiſition of their ſupporting ſubſtances not on changes of figure. This alſo appears from the reſiduum of the roſemary leaf, (lect. 4.), which retained all its fibres, hairs and lineaments perfect, as to figure and form, after that violence of fire which excited its own concrete fires to expand and break from their fetters of celeſtial matter that gave to the leaf firmneſs, weight and conſiſtency. For the luminous matter thus releaſed, expanded and flew off into the air, carrying with it elaſticity and all the lively powers of the burnt body; the celeſtial matter thus loſing the fires it had confined, which had been the cauſe of it's own concentration in the leaf, alſo followed its own propenſity and deſcended to the earth; and the inert matter, in which both had been emboſomed and contextured, retained the perfect figure of the leaf even in the moſt minute and undiſcernible parts, but without qualities, which ſhews that figure is not the principle of qualities, and that this matter had been in the moſt perfect and intimate ſolution and union with the two continuous fluids mentioned, without the poſſibility of admitting an undiſſolved or diſtinct particle.

Leaving then ſuch conjectures and hypothetic principles, which give play to the imagination, but ſatisfy not the judgment, let us conſider nature at large. All bodies, even metals, the hardeſt and firmeſt, are expanded, opened, diſſolved and reduced to fluidity by heat. Again, fuſed metals, and all liquids, even water, are made hard and firm by cold. Here it is not flat particles that conſtitute firmneſs, and round ones that produce fluidity; but two magiſterial powers that exerciſe their dominion over all bodies. Now it would be unphyſical to admit, much more ſo to aſcribe efficacy to a quality without a ſupporting ſubſtance. It muſt therefore be the exertion of the ſubſtances to which thoſe powers belong that produces thoſe changes in body. Conſequently, it is the expanſive matter, or light, which is a concrete in all bodies that thus opens, expands, and liquifies them, when excited and aided by an extraneous cauſe of it's own nature. And ſo it is the celeſtial matter, which ſhackles this down and gives firmneſs of texture, that condenſes them and renders them more hard, when reinforced by more of it's own ſpecies, which invades body and contracts it's dimenſions.

Theſe two primary principles, we have ſeen, (lect. 9.) are alternately gaining a maſtery over each other, according to the poſition of any given part of the earth, which by its diurnal and annual motions is ſucceſſively obverted to each of theſe great agents, whereby all bodies undergo the changes and operations neceſſary to bring them to the perfection peculiar to their nature. This perfection they originally received from the Creator of ſubſtances; and it is ſtill perpetuated by the efficacy of the Divine Law of Procreation, ſtamped by Omnipotence on the natures he formed, *Let each bring forth according to its kind.* By the efficacy of the Divine Word the matter of light, the matter of the heavens, and that of the earth got being in the full perfection and diſtinction of their eſſences and qualities; and by a like Word, the beings of the earth, animals, vegetables and foſſils, were formed of theſe three elementary matters. Now, ſince the correſponding bodies of this day are compoſed of the ſame matters, to what but the influence of theſe elements can we attribute their growth, encreaſe, properties, and perfection? For it would be abſurd to imagine, that God is continually creating new matter in the growing body; and contrary to experience to affirm that the ſame body continued in it's perfection ſince the Creation. Therefore, all bodies are generated, grow and come to perfection under the influence of theſe elementary matters, which, being their accretive ſubſtances, and endowed with eſſences adapted to all material functions, give to bodies every conſiſtency, whether hard or ſoft, firm or fluid, according to the decree of formation and preſervation paſſed at the Creation.

Whence then the rigid firmneſs of oak and of ſtones, the fuſibility of metals, the fluidity of water, the hardneſs of bones, the flexibility of ſinews, and the ſoftneſs of fleſh? How in a horſe or ox do the bones, ſinews, juices, ſpirits, veins and arteries get their various conſiſtencies, arrangement and properties, from the graſs on which the animal feeds? Will any philoſopher pretend to explain this by the various ſizes and figures of particles? No nor ſhall we, with the real and univerſal principles of nature, preſume to explain this otherwiſe than by the mandate of Omnipotence, that all bodies which at the Creation He formed in full perfection, *i. e.* adaption to their reſpective ends in nature, ſhould conſerve that ſtate and nature in ſucceſſion to the conſummation of ages. If then a philoſopher will enquire, by what mechaniſm the agents of nature diſpoſe themſelves now for the production of the various conſiſtencies, ſizes, forms, and organization of natural bodies, we muſt remit him back to the period of their Creation: and as he muſt allow, that the Word of Omnipotence was the directing principle of their formatian out of the created elements, ſo he muſt admit the ſame word of efficacy to be the governing principle of their renewal and preſervation in texture, conſiſtency, organization and diſtinctive properties now as well as then. This is the voice of revelation, *He ſaid and they were made*; *He ſaid, let each bring forth according to it's kind*, and it was ſo. This is the *ultimatum* of philoſophy, which muſt be founded in the knowledge of God, or it has no real foundation, and muſt terminate in the acknowledgment of GOD, or it terminates in *Chimera*.

FINIS.

ERRATA.

Page 168, line 24, for Whiſton's read Gregory's.
178, l. 5, fig. 2d. read fig. 1ſt.
207, l. 13, fig. 3d. read fig. 2d.
208, l. 13, fig. 2d. read fig. 3d.